NATIONAL BUREAU OF STANDARDS REPORT

7079

AN ANALYSIS OF ELECTRICAL ENERGY USAGE IN AIR FORCE HOUSES EQUIPPED WITH AIR-TO-AIR HEAT PUMPS

by

Paul R. Achenbach
and
Joseph C. Davis

Report to

Office of the Chief of Engineers
Bureau of Yards and Docks
Headquarters, U. S. Air Force
Washington 25, D. C.

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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Mechanical Systems Section
Building Research Division

to
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ABSTRACT

An analysis was made of the electric energy usage for all purposes in 16 sample houses selected from a total of 1535 houses constructed at Little Rock Air Force Base to domicile Air Force personnel. Of principal interest was the energy used by the air-to-air heat pumps installed for all-year air conditioning and the effect of electric energy used by other appliances on the heating and cooling loads in the houses. The data revealed that the annual energy usage in the 16-house sample averaged 25,300 KWH, of which approximately half was used by the heat pump and its auxiliary resistance heaters, about one fourth was used for water heating, and the remaining one fourth was used for the electric range and miscellaneous devices. It was determined that the energy used by appliances, other than the heat pump, which contributed toward heating the house was about half the amount used by the heat pump during the winter months. An average winter energy usage factor of about 2.2 KWH/degree-day (1,000 sq ft of floor area) was observed for the sample houses based on all the energy that contributed toward heating and the degree-days determined from average indoor and outdoor temperatures. The average summer energy usage factor was 2.1 KWH/degree-day (1,000 sq ft of floor area) based on the energy used by the heat pump for cooling and the degree-days determined from hourly values of outdoor temperature related to a reference value of 65°F. An analysis of the demand charts revealed that the monthly maximum power demand for the entire housing area was probably caused by a moderately high sustained demand in many houses rather than a coincidence of the maximum demands in a smaller number of houses. The pattern of average daily power demand indicated that some type of programming device that caused the water heater to be energized only during periods of low or moderate demand by other appliances offered the best possibility of distributing the daily energy usage more evenly over the 24-hour period. The effect of several types of programming devices on the pattern of power demand is discussed.

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1. INTRODUCTION

The National Bureau of Standards in collaboration with the United States Air Force is engaged in a study of all-year air conditioning systems in a number of Air Force housing projects. One part of this study is comprised of an analysis of electrical energy usage and electrical demand data obtained from a sample group of houses at Little Rock Air Force Base in Arkansas.

The Arkansas Power and Light Company, the electric utility that serves the Little Rock Air Force Base, has been collecting electrical energy consumption data on 16 houses in the housing area since October 1958, using four or more demand meters on each house to record separately the energy used for the electric range, the electric water heater, the heat pump, and the total for the house on a 15-minute demand interval. Indoor air temperatures have also been recorded in each of the houses, and outdoor air temperatures were recorded at three separate stations in the housing area. The total monthly energy use indicated by these four meters in each of the 16 houses has been summarized by Arkansas Power and Light Company personnel.

These monthly summaries of energy usage and the original charts from the recording demand meters and the temperature recorders have been made available to the National Bureau of Standards for further analysis. This analysis was planned to develop the following information from the sample houses:

(a) The amount of electrical energy used by the occupants for cooking, water heating, house heating, and miscellaneous purposes,

(b) A correlation between the energy used by the heat pump, including the supplementary resistance heaters, and the outdoor temperature during both winter and summer operation, in houses of different size,

(c) An estimate of the contribution of the electrical equipment, other than the heat pump, to the heating of the house in the winter and to the cooling load in the summer,

(d) The components of the electrical equipment in the houses that contributed significantly to the monthly maximum 15-minute power demands in the 16 sample houses,

(e) The frequency of recurrence of 15-minute power demands of various magnitudes,

(f) One or more ways to effectively reduce the peak demands for the entire housing area without unduly altering the living habits of the house occupants.

2. DESCRIPTION OF SAMPLE HOUSES

The identification of the 16 houses used for the study with respect to location, type of house, floor area, exterior wall area, window and door area, and number of bedrooms is summarized in Table 1. House types A, A_1, B, and B_1 were used to domicile airmen, and house types C, D, E, F, and G were used primarily to domicile officers. House types A_1 and B_1 were of duplex construction with carports adjoining; house types A, B, C, and D were of duplex construction with living quarters adjoining; and the remainder were of detached design. All houses were of single-story construction built on concrete slabs on grade. Perimeter insulation on the floor slab consisted of 2 inches of rigid polystyrene foam. The insulation in the walls and ceiling consisted of 4 inches and 6 inches of glass fiber, respectively.

There were 1535 houses in the housing area, so the sample that was used for this study represented 1.04 percent of the total. The sample included six 2-bedroom units, eight 3-bedroom units, and two 4-bedroom units. The entire housing area was comprised of 465 2-bedroom units, 1067 3-bedroom units, and twelve 4-bedroom units. It is evident from these figures that the proportion of 4-bedroom units was much greater in the sample group of houses than for the entire housing area and that the proportion of 2-bedroom houses was somewhat greater in the sample than for the entire group.

The occupancy of the sample houses for the period from June 8, 1959 to March 8, 1960 is summarized in Table 2. This information was obtained from the housing officer at the air base.

Table 1

Identification of Sample Houses

Street Address of House	Contractor Identification No.	House Type	No. of Bedrooms	Floor Area, Gross ft^2	Floor Area, Net ft^2	Ext. Gross Wall Area, ft^2	Window and Door Area, ft^2
114 Minnesota Circle	4	B_1	3	1070	999	1056	219
122 Mississippi Loop	14	A_1	2	970	891	992	180
110 Missouri Circle	74	B	3	1070	1013	832	193
129 Georgia Avenue	163	B_1	3	1070	999	1056	219
189 Pennsylvania Drive	172	B	3	1070	1013	832	193
102 Florida Avenue	180	A	2	970	891	768	153
115 Idaho Circle	263	A	2	970	891	768	153
126 Montana Circle	301	A_1	2	970	891	992	180
103 Arizona Drive	467	F	4	1680	1553	1456	266
105 Arizona Drive	468	G	4	2050	1900	1604	267
102 Alabama Drive	577	E	3	1190	1115	1176	267
122 Illinois Drive	585	C	2	1050	999	832	166
130 Illinois Drive	587	D	3	1100	1046	916	193
129 Iowa Circle	656	D	3	1100	1046	916	193
123 Louisiana Drive	770	E	3	1190	1115	1176	267
127 Michigan Circle	843	C	2	1050	999	832	166

Table 2

Occupancy of Sample Houses

House No.	Period	Occupied or Vacant	Rank of Occupant	Size of Family
4	June 8, 1959 to March 8, 1960	Occupied	M/Sgt.	2 adults
14	June 8, 1959 to March 8, 1960	Occupied	M/Sgt.	2 adults 1 child
74	June 8, 1959 to March 8, 1960	Occupied	M/Sgt.	2 adults 2 children
163	June 8, 1959 to March 8, 1960	Occupied	T/Sgt.	2 adults 2 children
172	June 8, 1959 to Nov. 25, 1959	Occupied	Sgt.	2 adults
	Nov. 25, 1959 to Dec. 1, 1959	Vacant	---	---
	Dec. 1, 1959 to March 8, 1960	Occupied	M/Sgt.	2 adults 5 children
180	June 8, 1959 to March 8, 1960	Occupied	T/Sgt.	2 adults 1 child
263	June 8, 1959 to March 8, 1960	Occupied	T/Sgt.	2 adults 2 children
301	June 8, 1959 to March 8, 1960	Occupied	S/Sgt.	2 adults 2 children
467	June 8, 1959 to March 8, 1960	Occupied	Col.	2 adults 3 children
468	June 8, 1959 to March 8, 1960	Occupied	Col.	2 adults 3 children
577	June 8, 1959 to March 8, 1960	Occupied	Col.	2 adults 3 children
585	June 8, 1959 to June 30, 1959	Occupied	Capt.	2 adults 2 children
	June 30, 1959 to Aug. 4, 1959	Vacant	---	---
	Aug. 4, 1959 to Feb. 4, 1960	Occupied	1/Lt.	2 adults
	Feb. 4, 1960 to March 8, 1960	Vacant	---	---
587	June 8, 1959 to March 8, 1960	Occupied	CWO	2 adults
656	June 8, 1959 to Oct. 30, 1959	Vacant	---	---
	Oct. 30, 1959 to March 8, 1960	Occupied	1/Lt.	2 adults 3 children
770	June 8, 1959 to March 8, 1960	Occupied	Capt.	2 adults 2 children
843	June 8, 1959 to Nov. 7, 1959	Occupied	1/Lt.	2 adults 1 child
	Nov. 7, 1959 to March 8, 1960	Vacant	---	---

3. ANALYSIS OF DATA

3.1 Monthly Electric Energy Use

The average monthly electric energy use per house for each of the major components comprising the load and for the entire house was determined for the 16 houses as a group and also for the 2-bedroom, 3-bedroom, and 4-bedroom houses as sub-groups. These monthly averages have been summarized in Table 3 for the period from October 1958 to March 1960, inclusive. The average monthly energy use for the heat pump, the water heater, the kitchen range, and miscellaneous devices was also expressed in the table as a percentage of the average total house load in each sub-group and for the entire sample. Since the miscellaneous devices of the house such as lights, television, clothes dryer, and resistance heater in the bathroom were not metered separately, the energy use of these devices was determined by subtracting the sum of the usages of the heat pump, the water heater, and the range from the total energy use of the house. It will be noted in Table 3 that all of the 16 houses were not occupied prior to June 1959.

The average monthly energy use in the 16 houses for the several components of the total load was plotted in Figure 1 for the period from October 1958 to February 1960. The average monthly energy use per house for the entire housing area was also plotted as a dotted line in Figure 1 for comparison. This represents approximately 1535 houses starting with June 1959.

It will be noted in Figure 1 that the energy use for the heat pump and for the entire house reached an annual maximum in the middle of the winter and a smaller maximum during July and August. Two minimums occurred during the year, in April and October, approximately, for the heat pump and the house as a whole when little heating or cooling was required. The winter peak use of energy was approximately twice the summer maximum. The energy use for the water heater, the kitchen range, and the miscellaneous devices was relatively more stable throughout the year, although the minimum use of energy for water heating and the miscellaneous devices occurred in July and the maximums occurred in the colder months of the year.

Figure 1 shows that the average monthly energy used per house for the 16 houses was very close to that for 1535 houses for the period from July 1959 to February 1960 when the base was fully occupied, despite the disproportionate number of large houses in the 16-house sample.

Table 3

MONTHLY ELECTRIC ENERGY USAGE IN A
SELECTED GROUP OF HOUSES AT LITTLE ROCK AIR FORCE BASE

Year Month	1958 Oct.	1958 Nov.	1958 Dec.	1959 Jan.	1959 Feb.	1959 Mar.	1959 Apr.	1959 May	1959 June	1959 July	1959 Aug.	1959 Sept	1959 Oct.	1959 Nov.	1959 Dec.	1960 Jan.	1960 Feb.	1960 Mar.
Total Energy Used for Month, KWH																		
Avg for All Houses Reported	1469	2227	3683	3409	2292	1933	1379	1577	1729	1718	1901	1553	1570	2607	2575	3040	3707	2850
No. of Houses Reported	11	12	13	13	13	15	15	15	16	16	16	15	16	15	15	16	16	16
Avg for 2 Bedroom Houses	1040	1827	2800	2860	1860	1432	1008	1256	1473	1400	1467	1300	1347	2296	2352	2567	3160	2313
No. of 2 Bedroom Houses	3	3	4	4	4	5	5	5	6	6	6	6	6	5	5	6	6	6
Avg for 3 Bedroom Houses	1760	2280	3943	3246	2303	2030	1415	1593	1633	1845	1983	1483	1590	2603	2468	3025	3694	2885
No. of 3 Bedroom Houses	6	7	7	7	7	8	8	8	8	8	8	7	8	8	8	8	8	.8
Avg for 4 Bedroom Houses	1240	2640	4540	5080	3120	2800	2160	2320	2880	2160	2880	2560	2080	3400	3560	4520	5400	4320
No. of 4 Bedroom Houses	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	.2	2
Energy Used for Heat Pump, KWH																		
Avg for All Houses Reported	582	1243	2534	2200	1155	773	432	508	881	1025	1033	671	571	1365	1247	1589	2196	1506
Percent of Total	39.6	55.8	68.8	64.5	50.4	40.0	31.3	32.2	51.0	59.7	54.3	43.2	36.4	52.3	48.4	52.3	59.2	52.8
Avg for 2 Bedroom Houses	320	1020	2020	1945	1065	716	356	424	750	860	750	520	440	1188	1184	1430	2000	1413
Percent of Total	30.8	55.8	72.1	68.0	57.3	50.0	35.3	33.8	50.9	61.4	50.8	40.0	32.7	51.7	50.3	55.7	63.3	61.1
Avg for 3 Bedroom Houses	790	1209	2560	1994	1103	775	455	478	810	1018	1050	620	645	1368	1165	1508	2089	1355
Percent of Total	44.9	53.0	64.9	61.4	47.9	38.2	32.2	30.0	49.6	55.2	53.0	41.8	40.6	52.5	47.2	49.8	56.5	47.0
Avg for 4 Bedroom Houses	350	1700	3470	3430	1520	910	530	840	1560	1550	1810	1300	670	1800	1730	2390	3220	2390
Percent of Total	28.2	64.4	76.4	67.5	48.7	32.5	24.5	36.2	54.2	71.8	62.8	50.8	32.2	52.9	48.6	52.9	59.6	55.3
Energy Used for Water Heating, KWH																		
Avg for All Houses Reported	409	495	515	611	560	609	471	549	430	349	413	452	495	573	573	605	618	626
Percent of Total	27.9	22.2	14.0	17.9	24.4	31.5	34.1	34.8	24.9	20.3	21.7	29.1	31.5	22.0	22.2	19.9	16.7	22.0
Avg for 2 Bedroom Houses	347	420	415	480	425	460	368	460	393	293	353	410	457	492	500	510	477	453
Percent of Total	33.4	23.0	14.8	16.8	22.8	32.1	36.5	36.6	26.7	20.9	24.1	31.5	33.9	21.4	21.3	19.9	15.1	19.6
Avg for 3 Bedroom Houses	403	523	569	600	540	610	450	560	393	403	433	429	470	573	580	633	663	698
Percent of Total	22.9	22.9	14.4	18.5	23.4	30.0	31.8	35.2	24.1	21.8	21.8	28.9	29.5	22.0	23.5	20.9	17.9	24.2
Avg for 4 Bedroom Houses	520	510	530	910	850	980	810	730	690	300	515	660	670	780	730	810	860	860
Percent of Total	41.9	19.3	11.7	17.9	27.2	35.0	37.5	31.5	24.0	13.9	17.8	25.8	32.2	22.9	20.5	17.9	15.9	19.9
Energy Used for Cooking Range, KWH																		
Avg for All Houses Reported	62	103	97	91	83	88	65	81	58	53	68	67	79	88	88	111	118	93
Percent of Total	4.2	4.6	2.6	2.7	3.6	4.5	4.7	5.1	3.4	3.1	3.5	4.3	5.0	3.4	3.4	3.6	3.2	3.3
Avg for 2 Bedroom Houses	53	100	80	80	75	72	36	56	40	30	53	50	47	56	48	50	60	47
Percent of Total	5.1	5.5	2.9	2.8	4.0	5.0	3.6	4.5	2.7	2.1	3.6	3.8	3.5	2.4	2.0	1.9	1.9	2.0
Avg for 3 Bedroom Houses	77	126	126	100	91	95	80	100	70	73	80	80	103	108	110	165	165	130
Percent of Total	4.4	5.5	3.2	3.1	3.9	4.7	5.7	6.3	4.3	4.0	4.0	5.4	6.5	4.1	4.5	5.4	4.5	4.5
Avg for 4 Bedroom Houses	30	30	30	80	70	100	80	70	60	40	60	70	80	88	100	80	100	80
Percent of Total	2.4	1.1	0.6	1.6	2.2	3.6	3.7	3.0	2.1	1.9	2.1	2.7	3.9	2.6	2.8	1.7	1.8	1.9
Energy Used for Misc. Devices*, KWH																		
Avg for All Houses Reported	409	385	537	523	501	468	411	439	360	291	385	364	425	583	667	735	775	625
Percent of Total	27.9	17.3	14.6	15.3	21.9	24.2	29.8	27.8	20.8	16.9	20.2	23.4	27.1	22.4	25.9	24.2	20.9	21.9
Avg for 2 Bedroom Houses	320	240	285	405	295	280	248	316	290	217	310	320	403	568	620	577	623	400
Percent of Total	30.8	13.2	10.2	14.2	15.9	19.5	24.6	25.2	19.7	15.5	21.1	24.6	29.9	24.7	26.4	22.5	19.7	17.3
Avg for 3 Bedrooms	477	443	689	551	569	500	430	455	360	353	420	354	373	555	613	728	778	702
Percent of Total	27.1	19.4	17.5	17.0	24.7	24.6	30.4	28.5	22.0	19.1	21.2	23.9	23.4	21.3	24.8	24.1	21.1	24.3
Avg for 4 Bedrooms	340	400	510	660	680	810	740	680	570	270	500	530	660	730	1000	1240	1220	990
Percent of Total	27.4	15.2	11.2	13.0	21.8	28.9	34.3	29.3	19.8	12.5	17.3	20.7	31.7	21.5	28.1	27.4	22.6	22.9

* Include electric clothes dryer and bathroom heater

Considering the average values for all 16 houses, Table 3 shows that the energy used for the heat pump ranged from about 30% of the total load during the spring and fall to a value between 50 and 60% during the middle of the summer and winter; the energy used for water heating ranged from about 15% in the middle of the winter to a little over 30% in the spring and fall; the energy used for the kitchen range was 5% or less of the total throughout the year; and the energy used for miscellaneous devices ranged from 20 to 30% of the total most of the time.

Considering the 2-bedroom, 3-bedroom, and 4-bedroom houses as separate sub-groups, Table 3 shows that for most months of the year the energy used for the heat pump and for water heating increased with the number of rooms, whereas the energy used for cooking was usually the greatest in the 3-bedroom houses, and the energy used for miscellaneous devices was rather inconsistent with respect to house size.

The energy used in the sample houses for each component of the total load and the percent of the total represented by each component is summarized in Table 4 for the 12-month period from March 1959 to February 1960, inclusive. It should be noted that only 15 houses were occupied during some months of this period.

Table 4

Average Annual Energy Use in Sample Houses

Component of Load	Total Energy Used KWH	Percent of Total
Heat Pump	12,290	48.6
Water Heater	6,135	24.3
Range	965	3.8
Miscellaneous (by difference)	5,905	23.3
Total	25,295	100.0

Table 4 shows that the total energy used for heating and cooling by the heat pump on an annual basis was slightly less than that used for all other devices combined. The annual energy usages for water heating and miscellaneous devices were each about half as large as that for the heat pump.

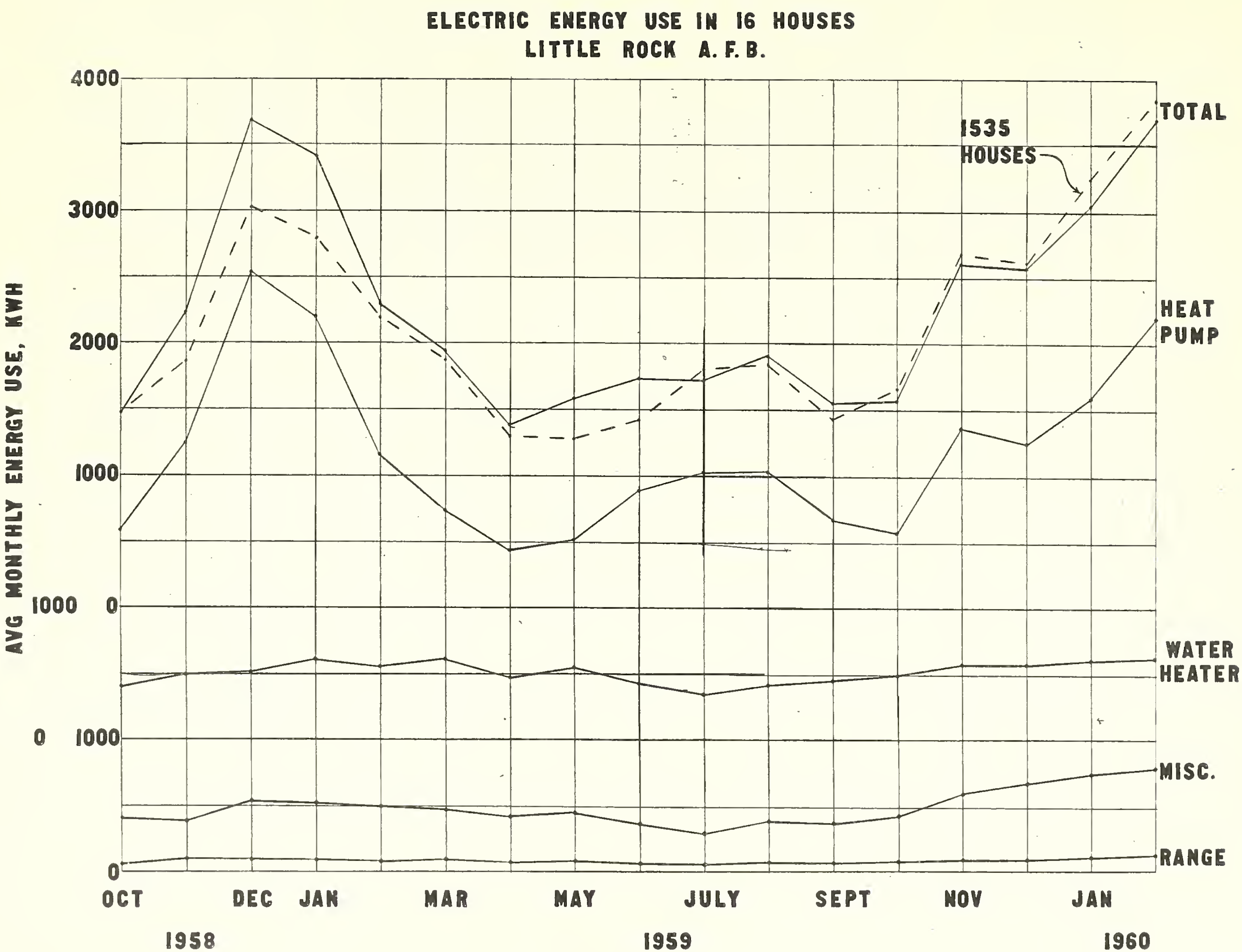

ELECTRIC ENERGY USE IN 16 HOUSES
LITTLE ROCK A. F. B.
AVG MONTHLY ENERGY USE, KWH
4000
3000
2000
1000
1000
0
0
1000
0
TOTAL
1535
HOUSES
HEAT
PUMP
WATER
HEATER
MISC.
RANGE
OCT
DEC
JAN
MAR
MAY
JULY
SEPT
NOV
JAN
1958
1959
1960

FIGURE 1

3.2 Heating Accomplished by Range, Water Heater, and Miscellaneous Devices

It is known that the energy used by the electric range, the electric water heater, and the miscellaneous devices each make some contribution toward warming the house in any season of the year. This auxiliary heating reduces the load on the heating system in cold weather and increases the load on the cooling system in hot weather.

It is probable that all of the energy input to the cooking range assists in warming the house with very little time lag except for the water vapor generated by the cooking processes that escape from the house in the winter time without being condensed. During the cooling season the water vapor produced by cooking would add to the latent cooling load on the heat pump and the sensible heat emitted from the range would add to the sensible cooling load of the heat pump. For this analysis it was assumed that all of the electrical energy used by the cooking range was effective in warming the house.

The jacket heat losses from the water heater would warm the house winter and summer, if the heater was located in the occupied space, and a variable fraction of the heat in the warm water used for bathing, dishwashing, and laundry would be transferred to the air in the house as sensible or latent heat. Observations of the electric energy required to maintain storage temperatures in the water tank in some of the sample houses during the night when no water was being drawn indicate that the jacket loss of these water heaters was 8 to 10 percent of the total monthly energy used for water heating. To make some allowance for the heat transferred to the air in the house from the hot water during use, it was assumed for this analysis that 15 percent of all the electrical energy supplied to the water heater was effective in warming the house.

It is probable that all of the electrical energy used by electric lights, resistance heaters, toasters, radio and television sets, and nearly all of the energy used by an electric iron would be converted into heat that would assist in warming a house. The situation with respect to an electric clothes dryer is less definite. Although there would be some heat transferred to the room from the jacket of the dryer, these devices are usually equipped with a small blower which uses room air to carry the water vapor and some sensible heat outside during the clothes-drying process. Such a blower, when in operation, would increase the infiltration into the house,

which would probably more than offset the jacket heat loss in the winter time. In the summer time the clothes dryer would increase the cooling load somewhat. For the purpose of this analysis, it was assumed that the clothes dryer contributed nothing toward heating the sample houses and that all of the remainder of the energy used by miscellaneous devices was converted into heat within the house.

The electrical energy used by the electric clothes dryers at Little Rock Air Force Base was not metered separately from the other miscellaneous loads. However, the energy used for this purpose in 15 sample houses at three other air bases where it was metered separately averaged about 100 KWH per house per month. Accordingly, the energy used for miscellaneous devices in the houses at Little Rock Air Force Base was corrected by subtracting 100 KWH from the monthly totals reported in each case where the monthly total exceeded 100 KWH.

On the basis of the foregoing assumptions, the monthly contribution of the electric range, water heater, and miscellaneous devices to house heating was determined by the following expression:

$$KWH_A = KWH_R + .15\ KWH_W + (KWH_M - 100) \quad \text{where}$$

KWH_A is the computed contribution of all appliances, other than the heat pump, to house heating in KWH/month,

KWH_R is the metered electric energy use of the electric range in KWH/month,

KWH_H is the metered electric energy use of the electric water heater in KWH/month,

KWH_M is the electric energy used by miscellaneous devices in KWH/month.

This formula was used later in this report for deriving one of the three factors for energy used per degree-day per 1,000 sq ft of floor area for the sample houses at Little Rock Air Force Base. It is recognized that this formula could probably be improved in accuracy by a careful statistical study of the heat dissipation characteristics of the various electrical appliances, as used in a house.

3.3 Correlation of Energy Requirements for Heating and Heating Degree-Days

Seasonal heat requirements for residences of similar construction in different climates and for different months in the same climate have often been compared on the basis of the number of degree-days occurring in each locality. The heat requirements of houses of similar size and construction are related to the length of the exterior walls and to the floor area. In an effort to correlate the energy requirements of the 16 sample houses at Little Rock Air Force Base during the heating season, three different energy usage factors were determined for the months of October, November, and December of 1959 and for January and February of 1960. These factors relate the electrical energy used and the floor area for each of the sample houses to the degree-days and have the units KWH/degree-day (1,000 sq ft). The data involved in determining the factors and the factors themselves are summarized in Tables 5 to 9, inclusive, for the 5 months studied.

The three energy usage factors shown in Figures 5 to 9 each involved the floor area of the house, but employed different values for the electrical energy used for heating the house and different bases for computing the degree-days. The first factor was computed from the electrical energy used by the heat pump plus the contribution to heating made by all other appliances and the degree-days related to a 65°F base. The second factor was computed from the electrical energy used by the heat pump only and the degree-days related to a 65°F base. The third factor was computed from the electrical energy used by the heat pump plus the contribution to heating made by all other appliances and the degree-days based on the difference between the monthly average indoor and outdoor temperatures.

An examination of Tables 5 to 9 indicates that the methods employed to obtain the energy usage factors correlate the observed data for 2-, 3-, and 4-bedroom houses for the months from October 1959 to February 1960 reasonably well. The second factor, obtained from the energy consumption of the heat pump only and the degree-days related to a 65°F base, did not differ by more than 15% in four of the five months from the third factor, obtained from the total energy used for heating and degree-days based on average indoor-outdoor temperature difference. For the five months studied, the second energy usage factor averaged 2.12 KWH/degree-day

Table 5

Relation of Energy Usage and Degree-Days
Under Heating Conditions for
October 1959
Little Rock Air Force Base

Contractors House Number	Energy Consumption: Heat Pump KWH	Energy Consumption: Appliance Contribution KWHA KWH	Energy Consumption: Total for Heating KWH	Avg Indoor Temp °F	Avg Outdoor Temp °F	Degree-Days: Based on 65° References	Degree-Days: Based on Avg Indoor -Outdoor Temp	Inside Floor Area sq ft	Energy Usage Factor, KWH/Deg-Days (1000 sq ft): Total, 65° Base	Energy Usage Factor, KWH/Deg-Days (1000 sq ft): Heat Pump, 65° Base	Energy Usage Factor, KWH/Deg-Days (1000 sq ft): Total, Indoor-Outdoor, ΔT
2-Bedroom Houses											
14	440	469	909	78	59	214	589	891	4.8	2.3	1.7
180	380	529	909	74	59	214	465	891	4.8	2.0	2.2
263	380	484	864	75	59	214	496	891	4.5	2.0	2.0
301	360	423	783	73	59	214	434	891	4.1	1.9	2.1
585	640	366	1006	78	59	214	589	999	4.7	3.0	1.7
843	440	240	680	70	59	214	341	999	3.2	2.1	2.0
Average	440	419	859	75	59	214	486	927	4.4	2.2	2.0
Std. Dev.									0.57	0.35	0.20
3-Bedroom Houses											
4	520	385	905	75	59	214	465	999	4.2	2.4	1.9
74	580	295	875	76	59	214	527	1013	4.0	2.7	1.6
163	1240	607	1847	76	59	214	527	999	8.6	5.8	3.5
172	680	240	920	77	59	214	558	1013	4.3	3.1	1.6
577	400	623	1023	74	59	214	465	1115	4.3	1.7	2.0
587	500	380	880	73	59	214	434	1046	3.9	2.2	1.9
656	560	486	1046	77	59	214	558	1046	4.7	2.5	1.8
770	680	618	1298	74	59	214	465	1115	5.5	2.9	2.5
Average	645	454	1099	75	59	214	500	1043	4.9	2.9	2.1
Std. Dev.									1.46	1.17	0.59
4-Bedroom Houses											
467	380	782	1162	76	59	214	527	1553	3.5	1.1	1.4
468	960	699	1659	73	59	214	434	1900	4.1	2.4	2.0
Average	670	741	1411	75	59	214	481	1727	3.8	1.8	1.7
Std. Dev.									0.30	0.66	0.30
Avg for 16 Houses	571	477	1048	75	59	214	492	1085	4.6	2.5	2.0
Std. Dev., 16 Houses									1.14	0.97	0.48

Table 6

Relation of Energy Usage and Degree-Days
Under Heating Conditions for
November 1959
Little Rock Air Force Base

Contractors House Number	Energy Consumption: Heat Pump KWH	Energy Consumption: Appliance Contribution KWH_A KWH	Energy Consumption: Total for Heating KWH	Avg Indoor Temp °F	Avg Outdoor Temp °F	Degree-Days: Based on 65° References	Degree-Days: Based on Avg Indoor -Outdoor Temp	Inside Floor Area sq ft	Energy Usage Factor, KWH/Deg-Days (1000 sq ft): Total, 65° Base	Energy Usage Factor, KWH/Deg-Days (1000 sq ft): Heat Pump, 65° Base	Energy Usage Factor, KWH/Deg-Days (1000 sq ft): Total, Indoor-Outdoor, ΔT
2-Bedroom Houses											
14	1140	495	1635	76	45	640	930	891	2.9	2.0	2.0
180	920	668	1588	74	45	640	870	891	2.8	1.6	2.0
263	860	805	1665	76	45	640	930	891	2.9	1.5	2.0
301	1600	492	2092	72	45	640	810	891	3.7	2.8	2.9
585	1420	529	1949	77	45	640	960	999	3.0	2.2	2.0
843	620*	3*	623*	60*	45	640	450*	999	1.0*	1.0*	1.4*
Average	1188	499	1592	73	45	640	900	927	3.1	2.0	2.2
Std. Dev.									0.33	0.46	0.36
3-Bedroom Houses											
4	1220	502	1722	73	45	640	840	999	2.7	1.9	2.1
74	1180	597	1777	77	45	640	960	1013	2.8	1.8	1.8
163	2180	766	2946	71	45	640	780	999	4.6	3.4	3.8
172	1320	338	1658	76	45	640	930	1013	2.6	2.0	1.8
577	1300	781	2081	72	45	640	810	1115	2.9	1.8	2.3
587	1060	729	1789	73	45	640	840	1046	2.7	1.6	2.0
656	1160	618	1778	78	45	640	990	1046	2.7	1.7	1.7
770	1520	856	2376	72	45	640	810	1115	3.3	2.1	2.6
Average	1368	648	2016	74	45	640	870	1043	3.0	2.0	2.3
Std. Dev.									0.62	0.53	0.65
4-Bedroom Houses											
467	1840	837	2677	73	45	640	840	1553	2.7	1.8	2.0
468	1760	837	2597	73	45	640	840	1900	2.2	1.5	1.6
Average	1800	837	2637	73	45	640	840	1727	2.5	1.7	1.8
Std. Dev.									0.25	0.16	0.20
Avg for 16 Houses	1365	616	2022	73	45	640	876	1085	2.8	1.9	2.2
Std. Dev., 16 Houses									0.54	0.50	0.54

* House 843 apparently not occupied. These data not included in the average.

Table 7

Relation of Energy Usage and Degree-Days
Under Heating Conditions for
December 1959
Little Rock Air Force Base

Contractors House Number	Energy Consumption: Heat Pump KWH	Energy Consumption: Appliance Contribution KWH_A KWH	Energy Consumption: Total for Heating KWH	Avg Indoor Temp °F	Avg Outdoor Temp °F	Degree-Days: Based on 65° References	Degree-Days: Based on Avg Indoor -Outdoor Temp	Inside Floor Area sq ft	Energy Usage Factor, KWH/Deg-Days (1000 sq ft): Total, 65° Base	Heat Pump, 65° Base	Total, Indoor-Outdoor, ΔT
2-Bedroom Houses											
14	1140	535	1675	77	43	643	1054	891	2.9	2.0	1.8
180	760	732	1492	73	43	643	930	891	2.6	1.3	1.8
263	1080	859	1939	77	43	643	1054	891	3.4	1.9	2.1
301	1742	529	2271	73	43	643	930	891	4.0	3.0	2.7
585	1200	560	1760	77	43	643	1054	999	2.7	1.9	1.7
843	1000*	306*	1306*	69*	43	643	806*	999	2.0*	1.6*	1.6*
Average	1184	643	1847	75	43	643	1004	927	2.9	2.0	2.0
Std. Dev.									0.65	0.53	0.36
3-Bedroom Houses											
4	1320	390	1710	74	43	643	961	999	2.7	2.1	1.8
74	980	677	1657	75	43	643	992	1013	2.6	1.5	1.6
163	1700	720	2420	74	43	643	961	999	3.8	2.6	2.5
172	980	278	1258	71	43	643	868	1013	1.9	1.5	1.4
577	1140	1016	2156	71	43	643	868	1115	3.0	1.6	2.2
587	720	824	1544	72	43	643	899	1046	2.3	1.1	1.6
656	1140	735	1875	78	43	643	1085	1046	2.8	1.7	1.7
770	1340	1036	2376	72	43	643	899	1115	3.3	1.9	2.4
Average	1165	710	1875	73	43	643	942	1043	2.8	1.8	1.9
Std. Dev.									0.55	0.42	0.39
4-Bedroom Houses											
467	1540	926	2466	72	43	643	899	1553	2.5	1.5	1.8
468	1920	1293	3213	74	43	643	961	1900	2.7	1.6	1.8
Average	1730	1110	2840	73	43	643	930	1727	2.6	1.6	1.8
Std. Dev.									0.10	0.06	0.0
Avg for 16 Houses	1247	741	1994	74	43	643	961	1085	2.8	1.8	1.9
Std. Dev., 16 Houses									0.52	0.47	0.37

* House #843 apparently not occupied. These data not included in average.

Table 8

Relation of Energy Usage and Degree-Days
Under Heating Conditions for
January 1960
Little Rock Air Force Base

Contractors House Number	Energy Consumption			Avg Indoor Temp	Avg Outdoor Temp	Degree-Days		Inside Floor Area	Energy Usage Factor, KWH/Deg-Days (1000 sq ft)		
	Heat Pump KWH	Appliance Contribution KWH_A KWH	Total for Heating KWH	°F	°F	Based on 65° References	Based on Avg Indoor -Outdoor Temp	sq ft	Total, 65° Base	Heat Pump, 65° Base	Total, Indoor-Outdoor, ΔT
						2-Bedroom Houses					
14	1440	458	1898	76	42	694	1054	891	3.1	2.3	2.0
180	1160	601	1761	73	42	694	961	891	2.8	1.9	2.1
263	1160	694	1854	75	42	694	1023	891	3.0	1.9	2.0
301	2040	658	2698	74	42	694	992	891	4.4	3.3	3.1
585	1400	595	1995	76	42	694	1054	999	2.9	2.0	1.9
843	1380	613	1993	73	42	694	961	999	2.9	2.0	2.1
Average	1430	603	2033	75	42	694	1007	927	3.2	2.2	2.2
Std. Dev.									0.57	0.51	0.41
						3-Bedroom Houses					
4	1400	825	2225	74	42	694	992	999	3.2	2.0	2.2
74	1020	934	1954	73	42	694	961	1013	2.8	1.5	2.0
163	2580	858	3438	74	42	694	992	999	5.0	3.7	3.5
172	1800	609	2409	74	42	694	992	1013	3.4	2.6	2.4
577	1400	1076	2476	71	42	694	899	1115	3.2	1.8	2.5
587	840	1040	1880	73	42	694	961	1046	2.6	1.2	1.9
656	1340	729	2069	77	42	694	1085	1046	2.9	1.9	1.8
770	1680	1019	2699	73	42	694	961	1115	3.5	2.2	2.5
Average	1508	886	2394	74	42	694	980	1043	3.3	2.1	2.4
Std. Dev.									0.67	0.73	0.51
						4-Bedroom Houses					
467	2180	1418	3598	74	42	694	992	1553	3.3	2.0	2.3
468	2600	1265	3865	73	42	694	961	1900	3.0	2.0	2.1
Average	2390	1342	3732	74	42	694	976	1727	3.2	2.0	2.2
Std. Dev.									0.17	0.0	0.10
Avg for 16 Houses	1589	837	2426	74	42	694	990	1085	3.3	2.2	2.3
Std. Dev., 16 Houses									0.61	0.57	0.41

Table 9

Relation of Energy Usage and Degree-Days
Under Heating Conditions for
February 1960
Little Rock Air Force Base

Contractors House Number	Energy Consumption: Heat Pump KWH	Energy Consumption: Appliance Contribution KWH_A KWH	Energy Consumption: Total for Heating KWH	Avg Indoor Temp °F	Avg Outdoor Temp °F	Degree-Days: Based on 65° References	Degree-Days: Based on Avg Indoor -Outdoor Temp	Inside Floor Area sq ft	Energy Usage Factor, KWH/Deg-Days (1000 sq ft): Total, 65° Base	Energy Usage Factor: Heat Pump, 65° Base	Energy Usage Factor: Total, Indoor-Outdoor, ΔT
2-Bedroom Houses											
14	1780	670	2450	75	34	908	1189	891	3.0	2.2	2.3
180	1800	504	2304	73	34	908	1131	891	2.8	2.2	2.3
263	1720	528	2248	73	34	908	1131	891	2.8	2.1	2.2
301	3140	735	3875	72	34	908	1102	891	4.8	3.8	4.0
585	1760	716	2476	75	34	908	1189	999	2.7	1.9	2.1
843	1800	816	2616	74	34	908	1200	999	2.9	2.0	2.1
Average	2000	662	2662	74	34	908	1157	927	3.2	2.4	2.5
Std. Dev.									0.72	0.63	0.68
3-Bedroom Houses											
4	3000	842	3842	74	34	908	1160	999	4.2	3.3	3.3
74	1540	1158	2698	73	34	908	1151	1013	2.9	1.6	2.3
163	2800	803	3603	73	34	908	1131	999	4.0	3.1	3.2
172	2080	712	2792	*	34	908	----	1013	3.0	2.3	---
577	2160	1196	3356	69	34	908	1015	1115	3.3	2.1	3.0
587	1200	968	2168	71	34	908	1073	1046	2.3	1.3	1.9
656	1740	757	2497	75	34	908	1189	1046	2.6	1.8	2.0
770	2180	1099	2279	72	34	908	1102	1115	2.2	2.2	1.9
Average	2088	942	2904	72	34	908	1117	1043	3.1	2.2	2.5
Std. Dev.									0.70	0.66	0.60
4-Bedroom Houses											
467	2720	1072	3792	74	34	908	1160	1553	2.7	1.9	2.1
468	3800	1546	5346	71	34	908	1073	1900	3.1	2.2	2.6
Average	3260	1309	4569	73	34	908	1116	1727	2.9	2.1	2.4
Std. Dev.									0.20	0.14	0.26
Avg for 16 Houses	2449	971	3378	73	34	908	1130	1085	3.1	2.3	2.5
Std. Dev., 16 Houses									0.68	0.62	0.58

* No average.

(1,000 sq ft) whereas the third factor averaged 2.18 in the same units for all the sample houses. The equality of these two factors indicates that the total energy for heating, including the quantity KWH_A, bore the same relationship to the degree-days based on indoor-outdoor temperature difference as the heat pump energy did to the degree-days based on a 65°F reference value. Or in other words, it tends to corroborate the validity of the 65°F base for computing degree-days in relation to the energy used by the heat pump for heating. It will be noted that the appliance contribution, KWH_A, in Tables 5 to 9 ranged from 84 percent of the heat pump energy in October down to about 40 percent of this item in February based on the averages for 16 houses. Considering the 5 months from October 1959 to February 1960, inclusive, the computed appliance contribution toward heating the houses, KWH_A, averaged 50.4 percent of the energy used by the heat pump and 33.5 percent of all the energy used for heating the houses.

With one exception, the standard deviations shown in Tables 5 to 9 among the 2-bedroom, 3-bedroom, and 4-bedroom houses as sub-groups and the entire 16-house sample, were progressively lower for the first, second, and third energy usage factors based on a 5-month average from October 1959 to February 1960. The exception occurred in the 4-bedroom houses for which the relative magnitude of the standard deviations for the first and second factors were in reverse order. This comparison of standard deviations indicates that the total energy used for heating did not correlate well with the degree-days of heating related to a 65°F base, but when the indoor temperature chosen by the occupants and the heating contributed by the miscellaneous equipment were taken into account as illustrated by the third factor, an improved correlation was obtained in the 16-house sample. It should be noted, however, that much less instrumentation is required to obtain the data for the second energy usage factor than for either of the other two in any field study.

3.4 Correlation of Energy Requirements for Cooling and Cooling Degree-Days

A similar relation of energy usage, floor area, and cooling degree-days was determined for the months of June, July, and August 1959 for the 16 sample houses. These data are summarized in Tables 10, 11, and 12.

The degree-day concept has been used to some extent for estimating the energy required for air conditioning residences during the cooling season. However, it has not had the same measure of acceptance for cooling conditions as for heating conditions. Under cooling conditions, the heat contributed by

electrical appliances added to the summer cooling load rather than assisting the heat pump as it did during the winter. Also, in the summer time, the outdoor temperature frequently crossed the reference value used for degree-day determinations whether the reference value chosen was 65°F or 75°F. Solar radiation on a house is a much greater factor in the total cooling load than it is for the heating load, and its effect is only indirectly reflected in the indoor-outdoor temperature difference during the summer. In addition, the degree-day concept makes no allowance for the cooling load represented by the humidity in the outdoor air used for ventilation.

Three energy usage factors were computed based on three different computations of the cooling degree-days. The degree-day values in columns 6 and 7 of Tables 10, 11, and 12 are based on the hourly values of outdoor temperature taken from the temperature recorder charts related to reference values of 65°F and 75°F, respectively. The degree-day values in column 8 of the tables were computed from the mean of the daily maximum and minimum outdoor temperatures and the daily average indoor temperature.

It will be noted in the tables that the energy usage factor for cooling varied over quite a range depending on the basis selected for determining the degree-days of cooling. An examination of Tables 10 to 12 indicates that the first two energy usage factors correlated the observed data for 2-, 3-, and 4-bedroom houses reasonably well for the three months studied. The percentage variation in each of these two factors in any given month for any group of houses was the same because the factors were related to each other by a fixed ratio: the ratio of the degree-days based on reference temperatures of 65°F and 75°F, respectively. However, the first factor provided a better correlation among the three separate months than did the second factor. The three monthly values for the 16-house average differed by only 10% for the first factor but differed by 27% for the second factor.

The third energy usage factor did not correlate the data among sub-groups or among the several months as well as the first two factors. Basing the degree-days on the difference between mean daily outdoor temperature and average indoor temperature is probably the least suitable of the three methods employed for correlating energy usage; first, because this temperature difference can become vanishingly small, or even

Table 10

Relation of Energy Usage and Degree-Days
Under Cooling Conditions for
June 1959
Little Rock Air Force Base

Contractors House Number	Energy Consumption: Heat Pump KWH	Energy Consumption: Appliance Contribution KWH_A KWH	Avg Indoor Temp °F	Avg Outdoor Temp °F	Degree-Days: Hourly Values, 65°F Base	Degree-Days: Hourly Values, 75°F Base	Degree-Days: Daily Mean Above Indoor Avg	Inside Floor Area sq ft	Energy Usage Factor KWH/Deg-Days (1000 sq ft): Hourly Values, 65°F Base	Energy Usage Factor: Hourly Values, 75°F Base	Energy Usage Factor: Daily Mean Above Indoor Avg
2-Bedroom Houses											
14	720	354	76	79	390	146	90	891	2.1	5.5	9.0
180	900	489	70	79	390	146	270	891	2.6	6.9	3.7
263	900	262	68	79	390	146	330	891	2.6	6.9	3.1
301	720	470	76	79	390	146	90	891	2.1	5.5	9.0
585	420*	162*	74*	79	390	146	150*	999	1.1*	2.9*	2.8*
843	840	179	73	79	390	146	180	999	2.1	5.8	4.7
Average	816	351	73	79	390	146	192	927	2.3	6.1	5.9
Std. Dev.									0.24	0.65	2.58
3-Bedroom Houses											
4	820	244	75	79	390	146	120	999	2.1	5.6	6.8
74	820	517	71	79	390	146	240	1013	2.1	5.5	3.4
163	960	555	73	79	390	146	180	999	2.5	6.6	5.3
172	780	289	73	79	390	146	180	1013	2.0	5.3	4.3
577	660	443	77	79	390	146	60	1115	1.5	4.0	9.9
587	880	424	71	79	390	146	240	1046	2.2	5.8	3.5
656	660	562	76	79	390	146	90	1046	1.6	4.3	7.0
770	900	147	73	79	390	146	180	1115	2.1	5.5	4.5
Average	810	397	74	79	390	146	184	1043	2.0	5.3	5.6
Std. Dev.									0.32	0.74	2.07
4-Bedroom Houses											
467	1560	579	74	79	390	146	150	1553	2.6	6.9	6.7
468	1560	688	76	79	390	146	90	1900	2.1	5.6	9.1
Average	1560	634	75	79	390	146	120	1727	2.4	6.2	7.9
Std. Dev.									0.26	0.65	1.20
Avg for 16 Houses	881	398	74	79	390	146	163	1085	2.2	5.7	6.0
Std. Dev., 16 Houses									0.35	0.85	2.30

* House 585 apparently not occupied. These data not included in average.

Table 11

Relation of Energy Usage and Degree-Days
Under Cooling Conditions for
July 1959
Little Rock Air Force Base

Contractors House Number	Energy Consumption: Heat Pump KWH	Energy Consumption: Appliance Contribution KWH_A KWH	Avg Indoor Temp °F	Avg Outdoor Temp °F	Degree-Days: Hourly Values, 65°F Base	Degree-Days: Hourly Values, 75°F Base	Degree-Days: Daily Mean Above Indoor Avg	Inside Floor Area sq ft	Energy Usage Factor KWH/Deg-Days (1000 sq ft): Hourly Values, 65°F Base	Energy Usage Factor KWH/Deg-Days (1000 sq ft): Hourly Values, 75°F Base	Energy Usage Factor KWH/Deg-Days (1000 sq ft): Daily Mean Above Indoor Avg
2-Bedroom Houses											
14	840	354	76	81	488	225	155	891	1.9	4.2	6.1
180	860*	6*	67*	81	488	225	434*	891	2.0*	4.3*	2.2*
263	1140	169	72	81	488	225	279	891	2.6	5.7	4.6
301	1040	463	76	81	488	225	155	891	2.4	5.2	7.5
585	440*	75*	74*	81	488	225	217*	999	0.9*	1.9*	2.0*
843	840	183	74	81	488	225	217	999	1.7	3.7	3.9
Average	965	292	75	81	488	225	202	927	2.2	4.7	5.5
Std. Dev.									0.37	0.79	1.37
3-Bedroom Houses											
4	1140	227	75	81	488	225	186	999	2.3	5.1	6.1
74	1000	640	72	81	488	225	279	1013	2.0	4.4	3.5
163	1360	481	74	81	488	225	217	999	2.8	6.0	6.3
172	720	328	76	81	488	225	155	1013	1.4	3.2	4.6
577	1100	569	76	81	488	225	155	1115	2.0	4.4	6.4
587	1000	286	72	81	488	225	279	1046	2.0	4.2	3.4
656	540	276	77	81	488	225	124	1046	1.1	2.1	4.2
770	1280	434	71	81	488	225	310	1115	2.4	5.1	3.7
Average	1018	405	74	81	488	225	213	1043	2.0	4.3	4.8
Std. Dev.									0.51	1.14	1.19
4-Bedroom Houses											
467	1540	185	74	81	488	225	217	1553	2.0	4.4	4.6
468	1560	325	76	81	488	225	155	1900	1.7	3.6	5.3
Average	1550	255	75	81	488	225	186	1727	1.9	4.0	5.0
Std. Dev.									0.17	0.40	0.36
Avg for 16 Houses	1079	351	74	81	488	225	206	1085	2.0	4.4	5.0
Std. Dev., 16 Houses									0.45	0.99	1.25

* Houses #180 and #585 apparently not occupied. These data not included in average.

Table 12

Relation of Energy Usage and Degree-Days
Under Cooling Conditions for
August 1959
Little Rock Air Force Base

Contractors House Number	Energy Consumption: Heat Pump KWH	Energy Consumption: Appliance Contribution KWH_A KWH	Avg Indoor Temp °F	Avg Outdoor Temp °F	Degree-Days: Hourly Values, 65°F Base	Degree-Days: Hourly Values, 75°F Base	Degree-Days: Daily Mean Above Indoor Avg	Inside Floor Area sq ft	Energy Usage Factor KWH/Deg-Days (1000 sq ft): Hourly Values, 65°F Base	Energy Usage Factor KWH/Deg-Days (1000 sq ft): Hourly Values, 75°F Base	Energy Usage Factor KWH/Deg-Days (1000 sq ft): Daily Mean Above Indoor Avg
2-Bedroom Houses											
14	840	400	76	79	447	170	93.0	891	2.1	5.5	10.1
180	900	380	70	79	447	170	279.0	891	2.3	6.0	3.6
263	680	68	76	79	447	170	93.0	891	1.7	4.5	8.2
301	1040	572	75	79	447	170	124.0	891	2.6	6.9	9.4
585	380	316	80	79	447	170	- 31.0	999	0.9	2.2	-12.3*
843	660	162	76	79	447	170	93.0	999	-1.5	3.9	7.1
Average	750	316	76	79	447	170	-	927	1.9	4.8	-
Std. Dev.									0.57	1.54	7.44
3-Bedroom Houses											
4	1240	276	74	79	447	170	155.0	999	2.8	7.3	8.0
74	1280	583	73	79	447	170	186.0	1013	2.8	7.5	6.8
163	1080	852	72	79	447	170	217.0	999	2.4	6.4	5.0
172	680	188	75	79	447	170	124.0	1013	1.5	4.0	5.4
577	880	543	77	79	447	170	62.0	1115	1.8	4.7	12.8
587	1360	274	73	79	447	170	186.0	1046	2.9	7.8	7.0
656	800	549	77	79	447	170	62.0	1046	1.7	4.5	12.4
770	1080	454	72	79	447	170	217.0	1115	2.2	5.7	4.5
Average	1050	465	74	79	447	170	151	1043	2.3	6.0	7.7
Std. Dev.									0.52	1.37	3.00
4-Bedroom Houses											
467	1740	438	74	79	447	170	155.0	1553	2.5	6.6	7.2
468	1880	635	77	79	447	170	62.0	1900	2.2	5.9	16.1
Average	1810	439	76	79	447	170	109	1727	2.4	6.3	11.7
Std. Dev.									0.14	0.34	4.40
Avg for 16 Houses	1032	434	75	79	447	170	-	1085	2.1	5.6	7.0
Std. Dev., 16 Houses									0.55	1.47	5.91

* Interior temp. 1°F above exterior temp.

negative, and yet the house can have a cooling requirement, and secondly, because a house probably responds with respect to the need for cooling or heating on a cycle of less than 24 hours. Note that the degree-day value for house No. 485 as used for the third factor was negative during August because the average indoor temperature was 1°F higher than the mean daily outdoor temperature even though the heat pump used 380 KWH of electrical energy during the month. This caused the corresponding energy usage factor to be negative.

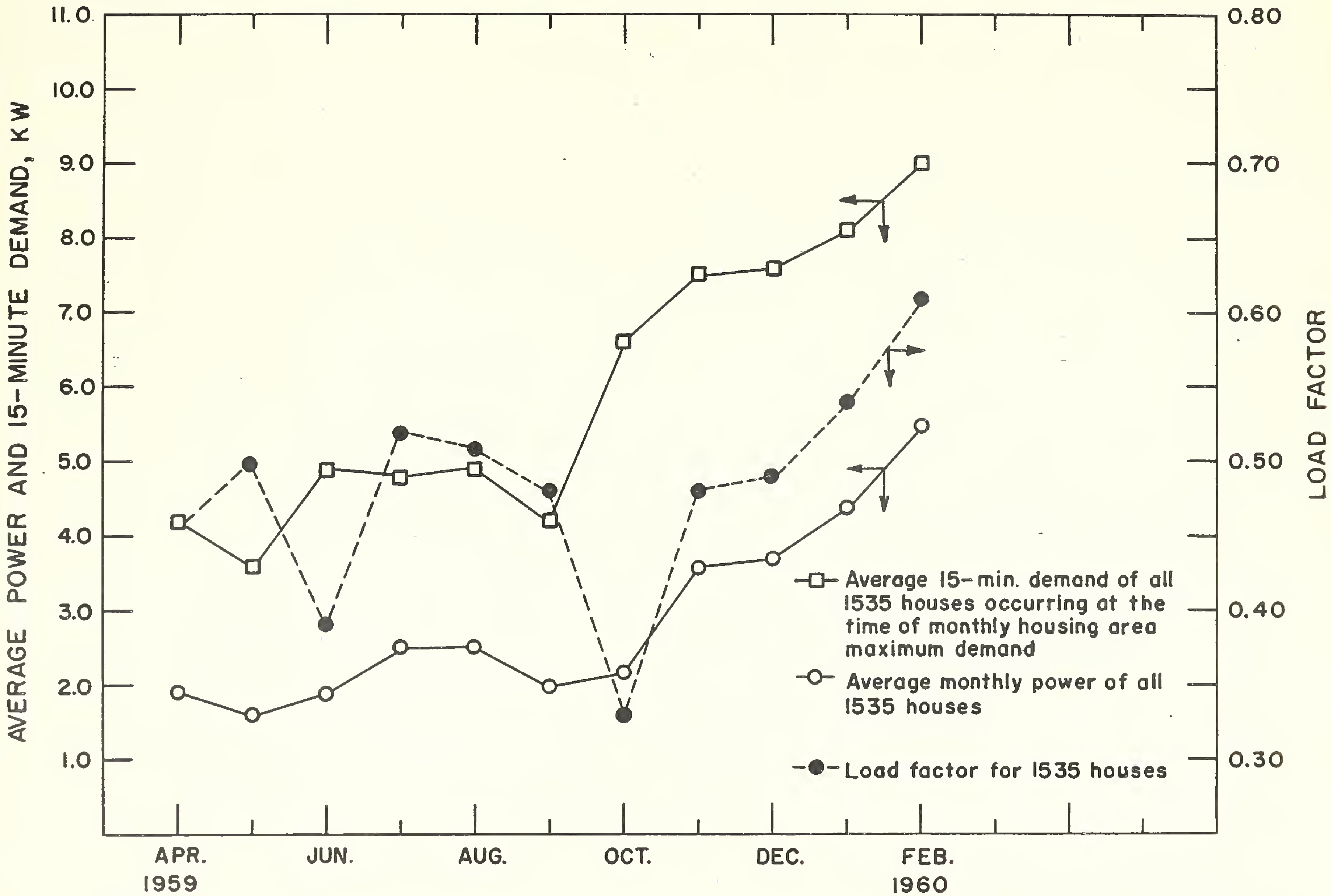
The standard deviations were progressively higher for the first, second, and third energy usage factors both within the sub-groups of houses and for the entire sample. The 3-month averages of the standard deviations for the first, second, and third factors were 0.37, 0.91, and 2.78, respectively. It should be noted that the standard deviation for the first and second factors for each month are related to each other in the same ratio as the degree-days based on reference temperatures of 65°F and 75°F, respectively.

3.5 Factors Affecting Maximum Power Demand for the Housing Area

The unit rate for electric energy at the Little Rock Air Force Base is related by sliding scales to the following three factors: (1) the total monthly usage of electric energy, (2) the magnitude of the maximum 15-minute power demand during the month, and (3) the load factor, i.e. the ratio of the monthly average use of the electric power to the maximum 15-minute demand of power for the month. For this type of rate structure, a reduction of the maximum 15-minute demand in any month would tend to lower the unit rate by virtue of its effect on the second and third factors above even if the total energy usage remained unchanged.

3.5(a) Load Factor

Figure 2 shows a graph of the average monthly power use of all 1535 houses from April 1959 to February 1960, inclusive. It also shows a graph of the average 15-minute demand of all 1535 houses occurring at the time of monthly maximum 15-minute demand for the entire housing area. The load factor for the entire housing area was determined month by month from these data and plotted in Figure 2 for the same period.


AVERAGE POWER AND 15-MINUTE DEMAND, KW
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.80
0.70
0.60
0.50
0.40
0.30
LOAD FACTOR
Average 15-min. demand of all 1535 houses occurring at the time of monthly housing area maximum demand
Average monthly power of all 1535 houses
Load factor for 1535 houses
APR. 1959
JUN.
AUG.
OCT.
DEC.
FEB. 1960
FIG. 2

The figure shows that the monthly load factor approximated 0.50 from April 1959 to December 1959, with two exceptions, and then rose sharply until it reached a value of about 0.60 during February 1960. This means that the maximum 15-minute demand for power was about twice the monthly average much of the time, with a lower ratio occurring during the colder months of the winter. A low load factor occurs for a given house when the various items of electrical equipment are energized for only a small percentage of the total time, but occasionally many or all of them are simultaneously energized for periods up to 15 minutes. When the short periods of simultaneous use of many components of the load in a number of houses occur at the same time, the load factor for the entire group is low.

3.5(b) Daily Pattern of Power Demand

In order to determine how the power demand varied throughout the day, the daily pattern of power demand was plotted for five of the sample houses for the months of January 1960 and August 1959. For these 2 months, the power used during each 15-minute period of the day was tabulated for the five houses. From these data the maximum and minimum demands that occurred on any day of the month and the average demand for all days of the month were plotted for each 15-minute period of a 24-hour day. This information is shown in Figures 3 to 7, inclusive, for January 1960 and in Figures 8 to 12 for August 1959.

Four of the five houses revealed similar changes in the average and maximum power demands between the day and night hours during the month of January. Starting in the morning at a time ranging from about 0630 to 0900 hours, the average and maximum power demands rose quickly to about twice that observed earlier in the morning and remained at a high level until 1 to 3 hours after noon when they decreased to a value only a little above the night demand. After about 2 hours at a low value, the power demand rose again to a smaller maximum about 1800 or 1900 hours and then gradually decreased to night level, before midnight in most cases. These similar daily patterns are shown in Figures 3 to 6, inclusive. These four figures indicate the following conclusions regarding the power demand:

(1) There is a high probability that the monthly maximum 15-minute power demand will occur between the hours of 0630 and 2000 and will be caused principally by the activities of the occupants during their waking hours.

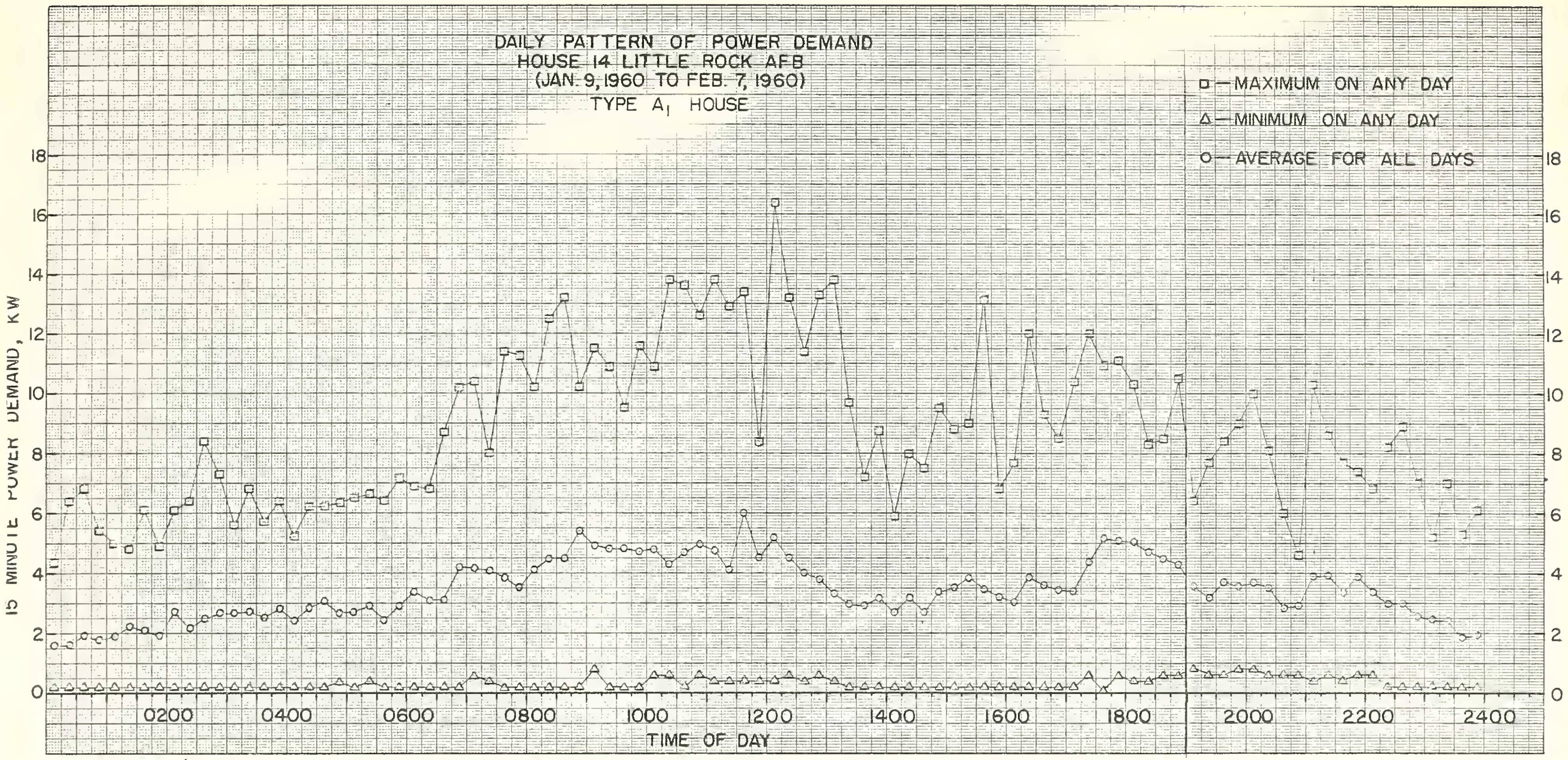

DAILY PATTERN OF POWER DEMAND
HOUSE 14 LITTLE ROCK AFB
(JAN. 9, 1960 TO FEB. 7, 1960)
TYPE A1 HOUSE
□ — MAXIMUM ON ANY DAY
Δ — MINIMUM ON ANY DAY
○ — AVERAGE FOR ALL DAYS
15 MINUTE POWER DEMAND, KW
0
2
4
6
8
10
12
14
16
18
0200
0400
0600
0800
1000
1200
1400
1600
1800
2000
2200
2400
TIME OF DAY

FIGURE 3

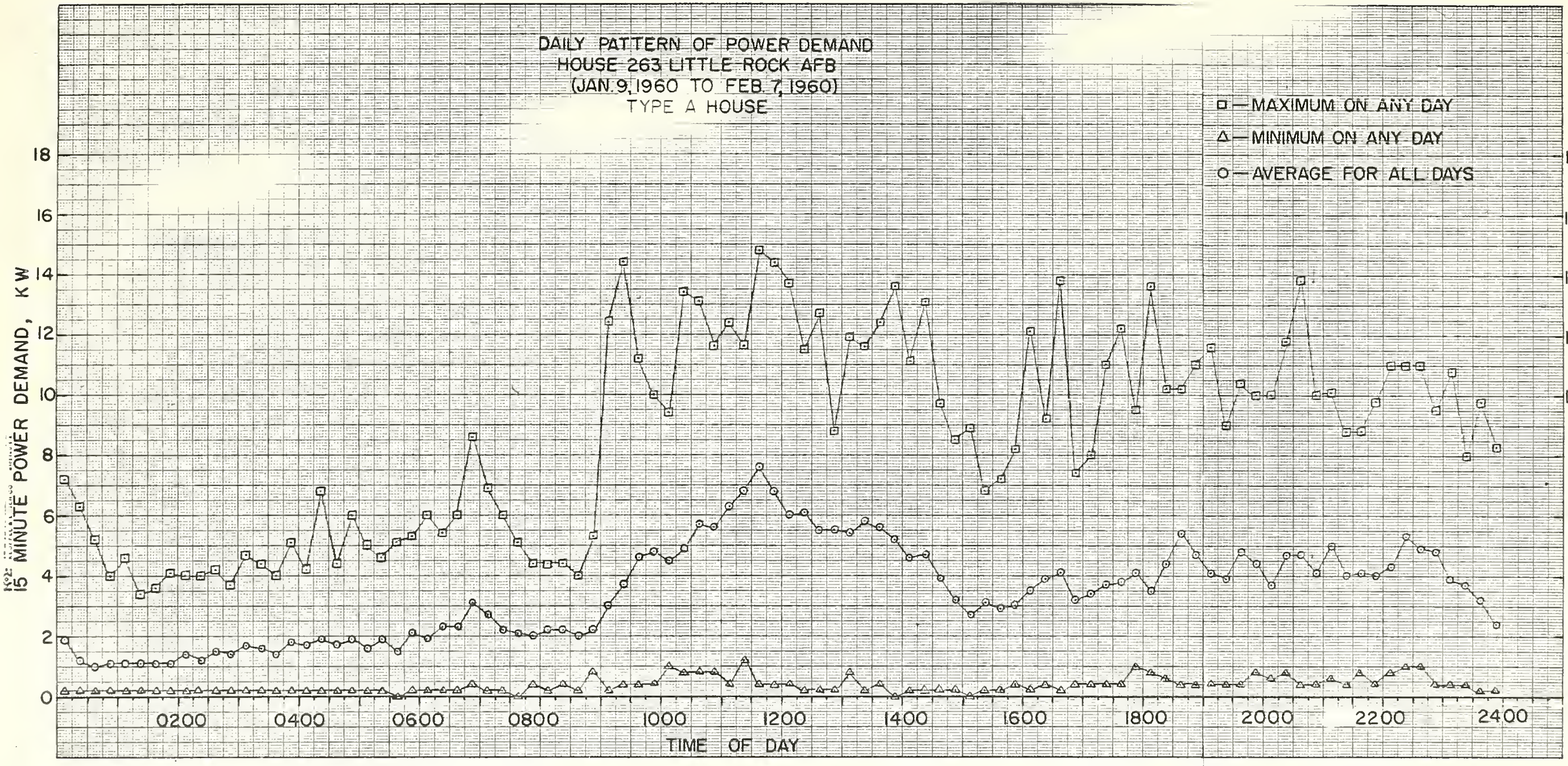
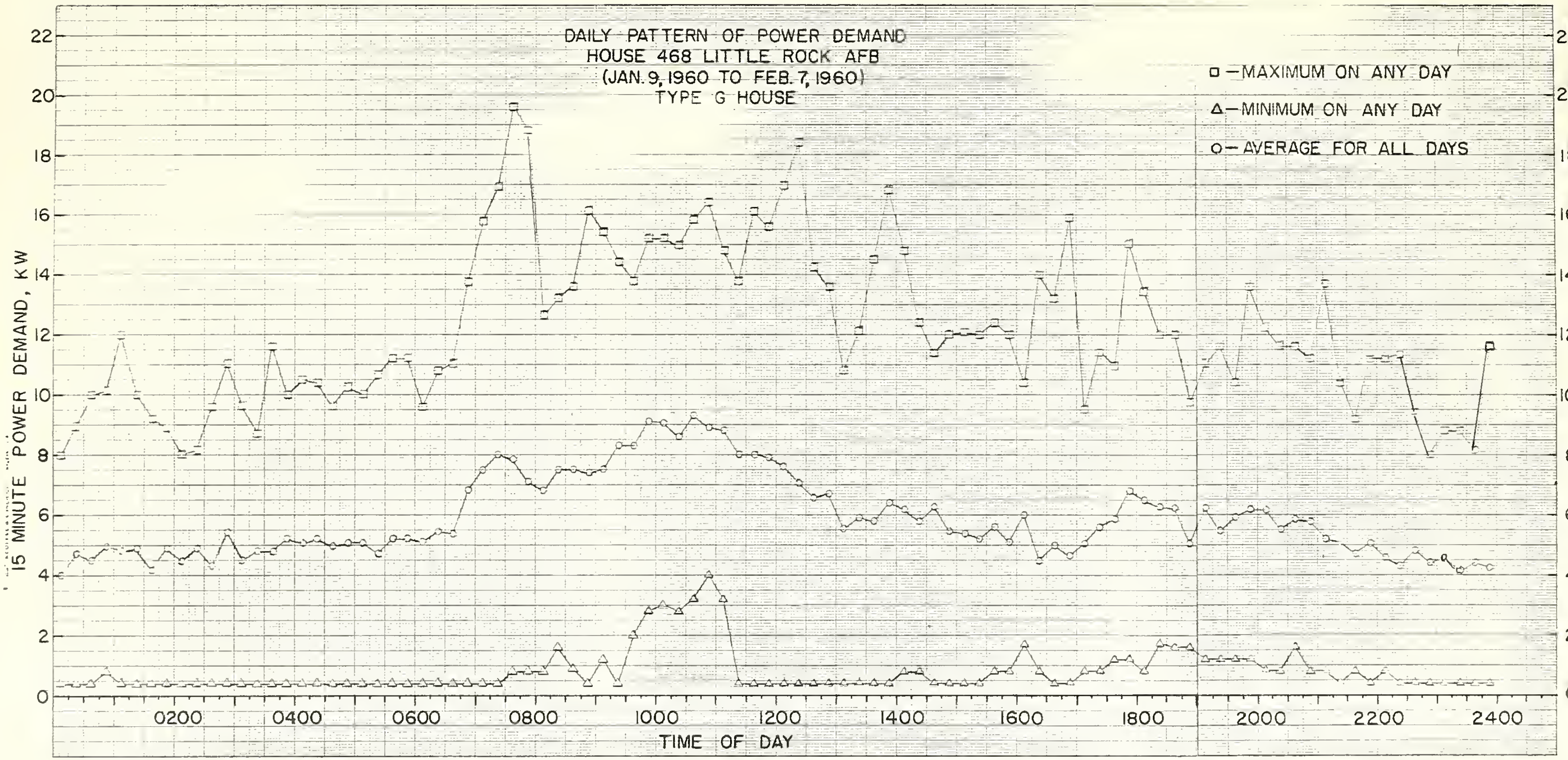

DAILY PATTERN OF POWER DEMAND
HOUSE 263 LITTLE ROCK AFB
(JAN.9,1960 TO FEB.7,1960)
TYPE A HOUSE
□ — MAXIMUM ON ANY DAY
Δ — MINIMUM ON ANY DAY
○ — AVERAGE FOR ALL DAYS
15 MINUTE POWER DEMAND, KW
TIME OF DAY
0200
0400
0600
0800
1000
1200
1400
1600
1800
2000
2200
2400
0
2
4
6
8
10
12
14
16
18

FIGURE 4



DAILY PATTERN OF POWER DEMAND
HOUSE 468 LITTLE ROCK AFB
(JAN. 9, 1960 TO FEB. 7, 1960)
TYPE G HOUSE
□ – MAXIMUM ON ANY DAY
Δ – MINIMUM ON ANY DAY
○ – AVERAGE FOR ALL DAYS
15 MINUTE POWER DEMAND, KW
0
2
4
6
8
10
12
14
16
18
20
22
0200
0400
0600
0800
1000
1200
1400
1600
1800
2000
2200
2400
TIME OF DAY

FIGURE 5

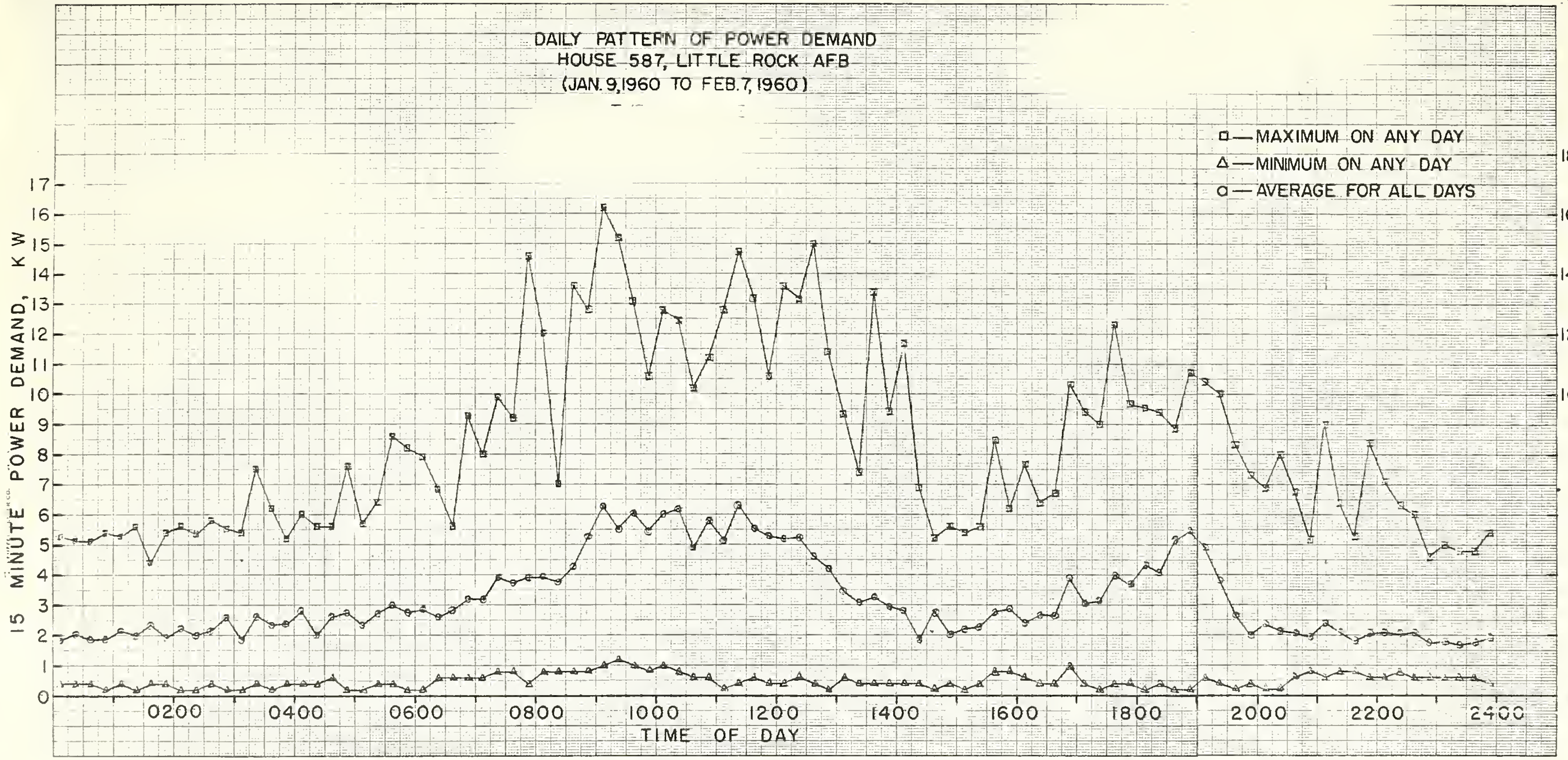
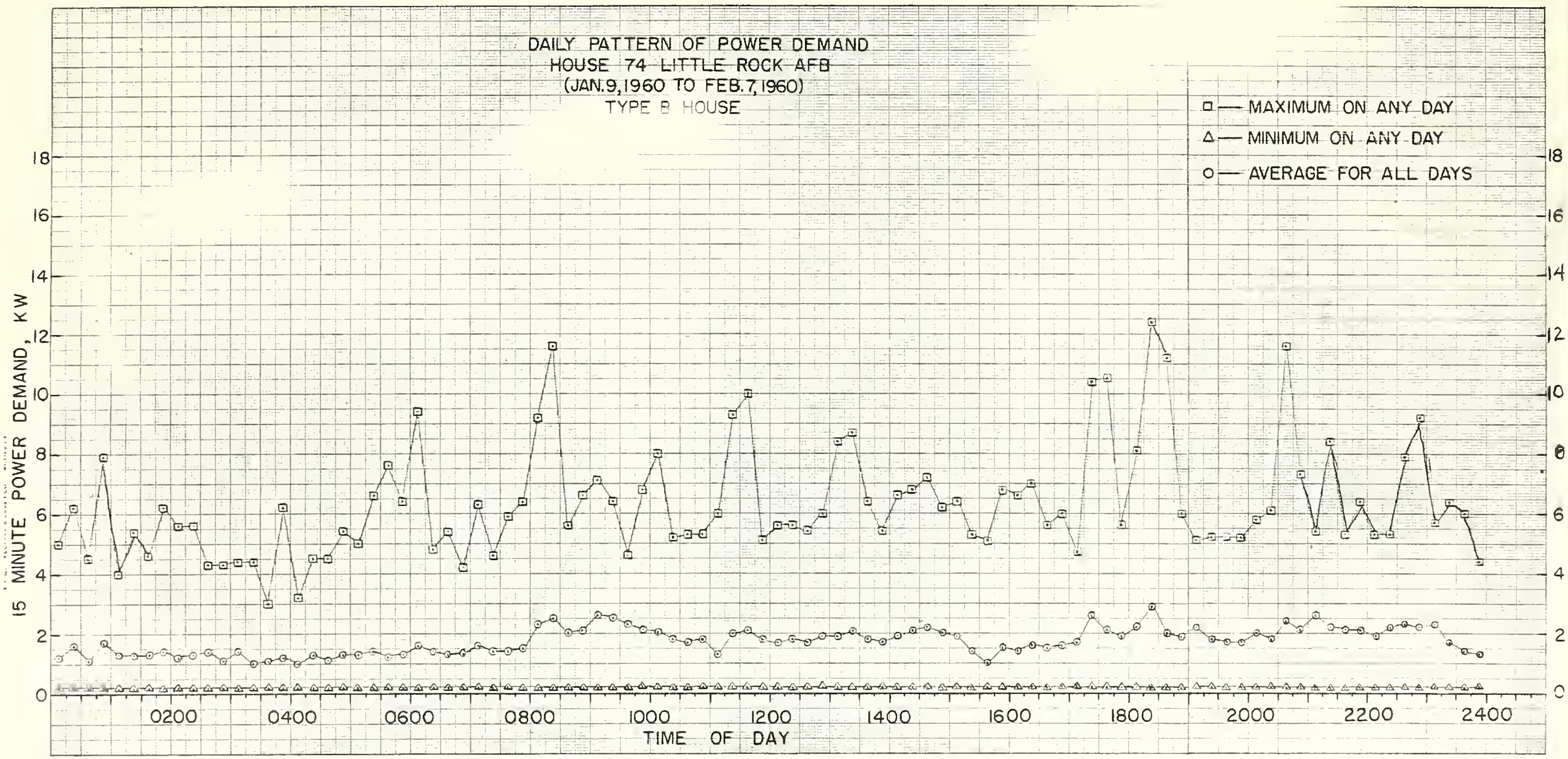

DAILY PATTERN OF POWER DEMAND
HOUSE 587, LITTLE ROCK AFB
(JAN. 9,1960 TO FEB.7,1960)
□ — MAXIMUM ON ANY DAY
Δ — MINIMUM ON ANY DAY
○ — AVERAGE FOR ALL DAYS
15 MINUTE POWER DEMAND, KW
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
0200
0400
0600
0800
1000
1200
1400
1600
1800
2000
2200
2400
TIME OF DAY

FIGURE 6



DAILY PATTERN OF POWER DEMAND
HOUSE 74 LITTLE ROCK AFB
(JAN. 9, 1960 TO FEB. 7, 1960)
TYPE B HOUSE
MAXIMUM ON ANY DAY
MINIMUM ON ANY DAY
AVERAGE FOR ALL DAYS
15 MINUTE POWER DEMAND, KW
TIME OF DAY
0200
0400
0600
0800
1000
1200
1400
1600
1800
2000
2200
2400

FIGURE 7

(2) The monthly maximum 15-minute power demand was not directly caused by the heating equipment during the coldest hours in the 24-hour period.

(3) A fairly stable power demand approximating twice the night level occurred during the hours between 0700 and 1400, more or less.

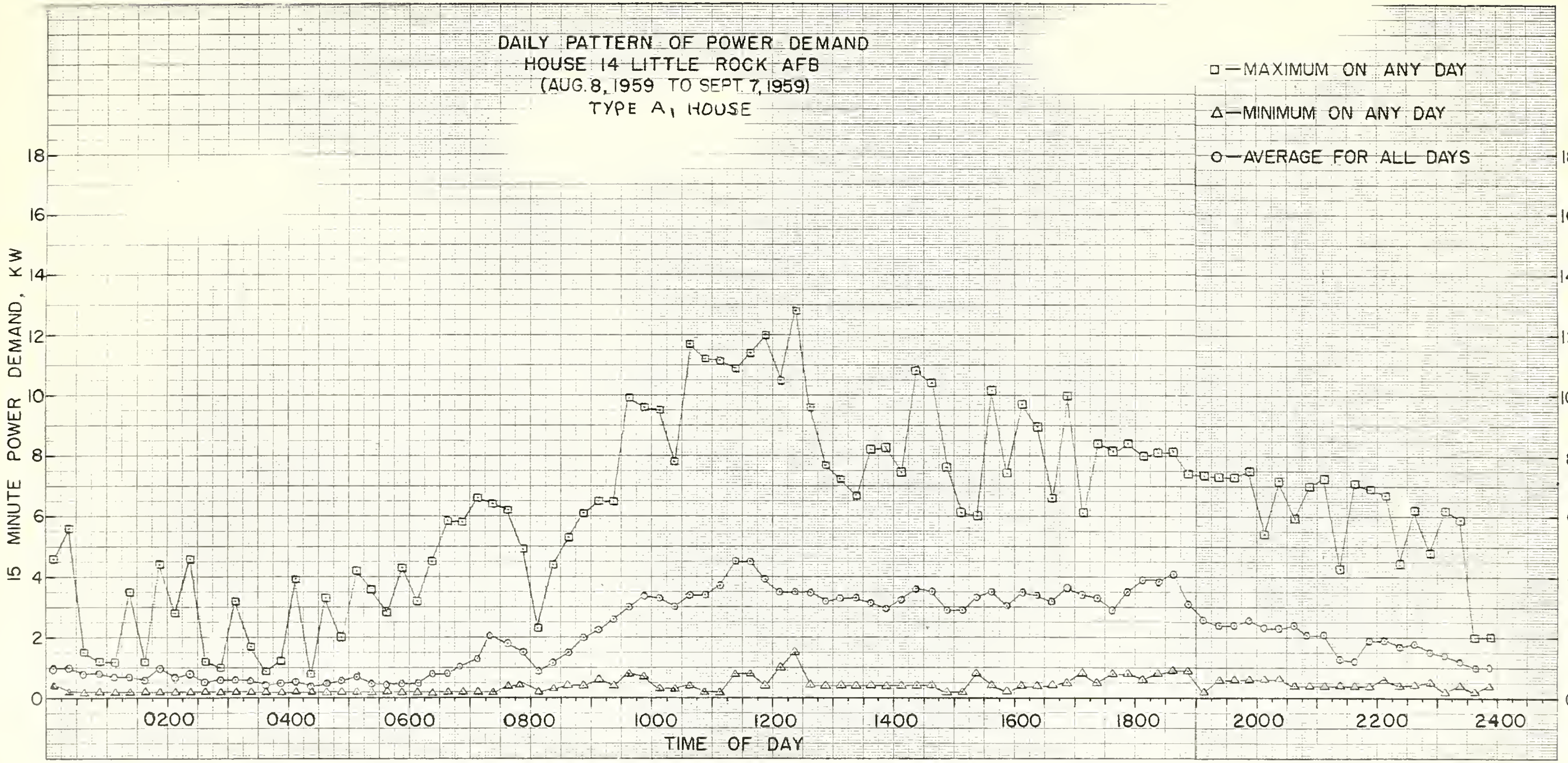
(4) Several high 15-minute demands occurred during the month that approximated the one monthly maximum value in each house.

(5) There was a high degree of similarity in the daily pattern of power demand in the four houses and therefore a good probability of coincidence of high or maximum values in a group of houses.

Despite the similarity in the daily patterns of power demand shown in Figures 3 to 6 for houses numbered 14, 263, 468, and 587; the pattern shown in Figure 7 for house 74 was significantly different. The variation in power demand between day and night was much less in this house, the monthly maximum 15-minute demand was lower, and high values in the maximum demand curve were more or less evenly scattered throughout the 24-hour period. Table 2 indicates that house 74 was not occupied by an unusually small family and Tables 5 to 9 show that the total monthly energy use in this house was of the same order of magnitude as houses 14, 263, and 587 during the winter months.

In August, the daily pattern of power demand was similar in all five houses studied, as shown in Figures 8 to 12. Starting in the morning between 0600 and 0900, the average and maximum power demand increased fairly rapidly for about 2 hours, after which it was reasonably stable until about 1900 hours and then gradually decreased until several hours after midnight. The daily average power demand was quite low from 0200 to 0600 hours ranging from about 0.5 KW in two of the houses up to about 1.5 KW in house 263. The daily average power demand during the period from 1000 to 1900 hours was in the range 3 to 4 KW in some houses and up to 6 KW or more in others.

Unlike the most prevalent daily pattern of power demand in January, there was no period of low demand in the middle of the afternoon in August. This is probably explained by the high solar load at this time of the day and the fairly steady requirement for heat pump operation.



DAILY PATTERN OF POWER DEMAND
HOUSE 14 LITTLE ROCK AFB
(AUG. 8, 1959 TO SEPT. 7, 1959)
TYPE A1 HOUSE
□—MAXIMUM ON ANY DAY
Δ—MINIMUM ON ANY DAY
o—AVERAGE FOR ALL DAYS
15 MINUTE POWER DEMAND, KW
0
2
4
6
8
10
12
14
16
18
0200
0400
0600
0800
1000
1200
1400
1600
1800
2000
2200
2400
TIME OF DAY

FIGURE 8

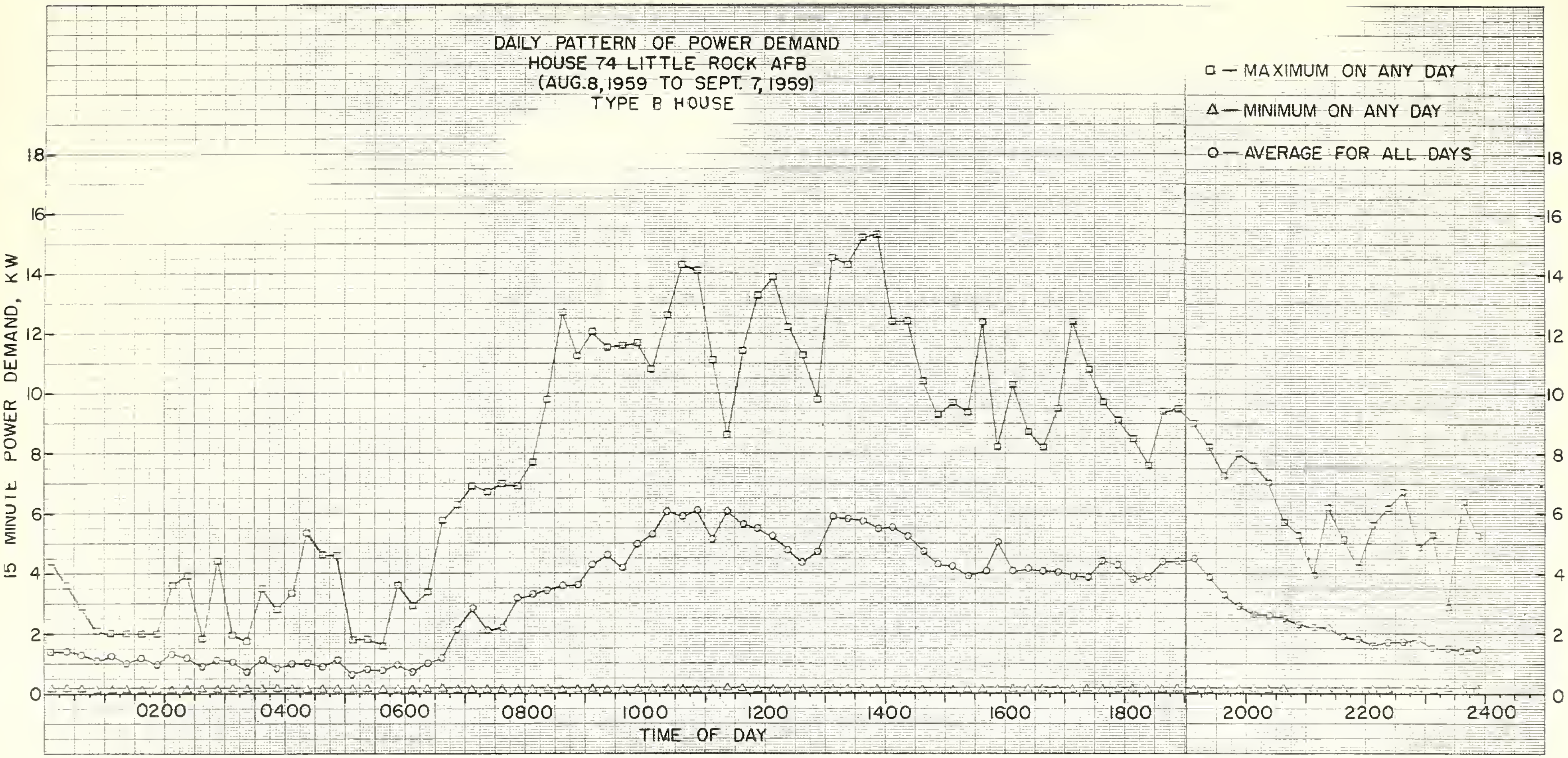
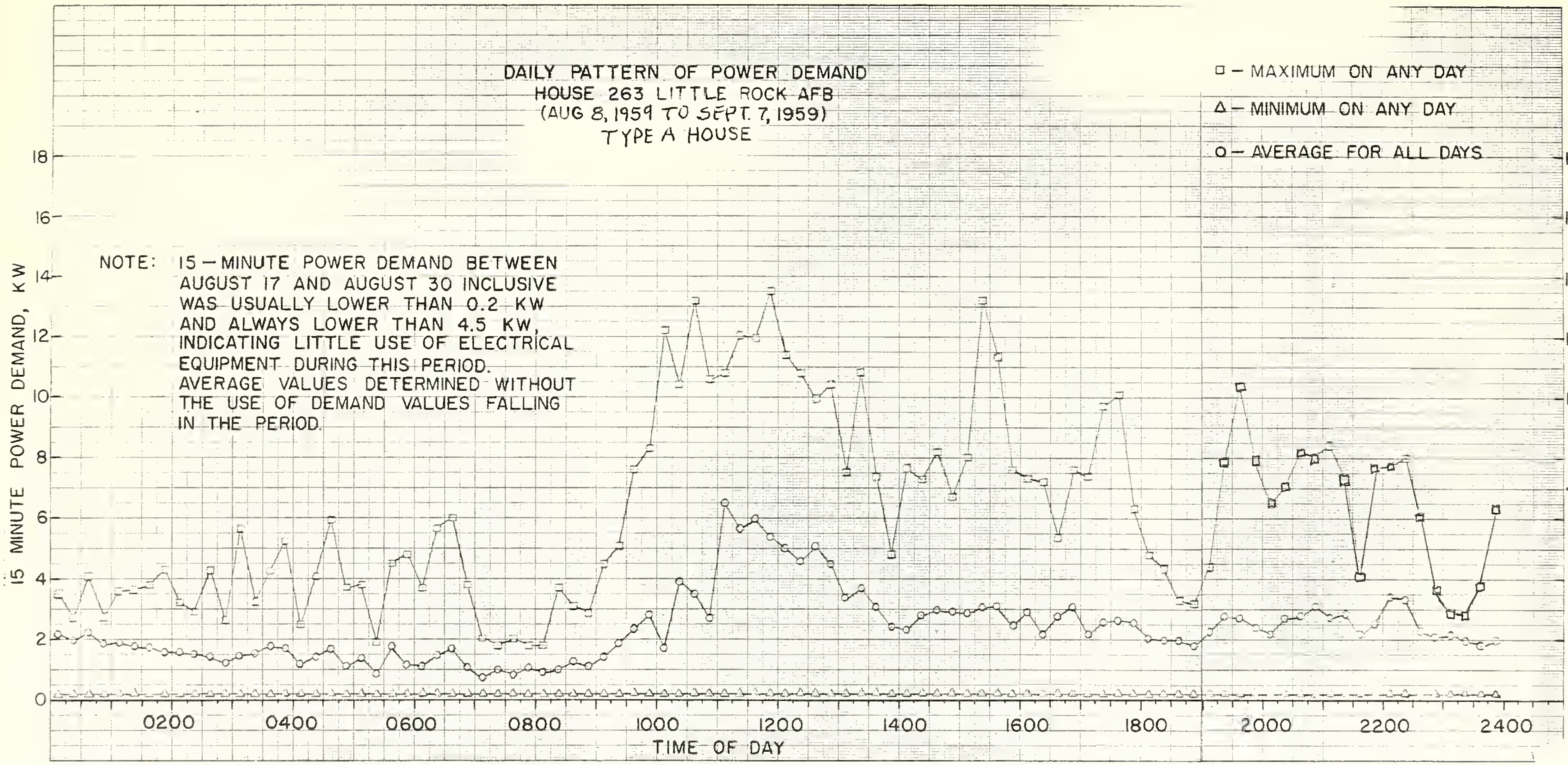
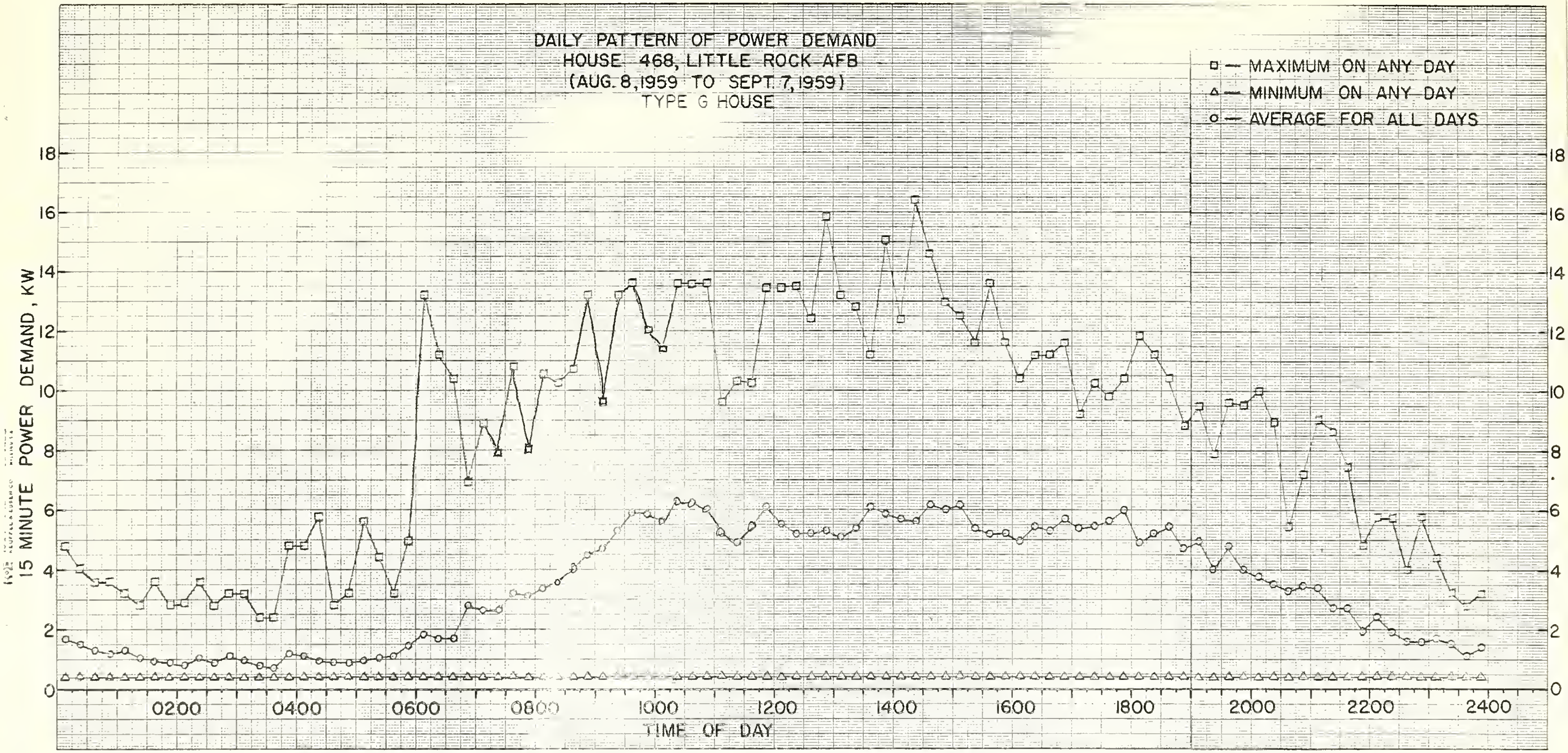

DAILY PATTERN OF POWER DEMAND
HOUSE 74 LITTLE ROCK AFB
(AUG.8, 1959 TO SEPT. 7, 1959)
TYPE B HOUSE
□ — MAXIMUM ON ANY DAY
Δ — MINIMUM ON ANY DAY
O — AVERAGE FOR ALL DAYS
15 MINUTE POWER DEMAND, KW
TIME OF DAY
0200
0400
0600
0800
1000
1200
1400
1600
1800
2000
2200
2400
0
2
4
6
8
10
12
14
16
18

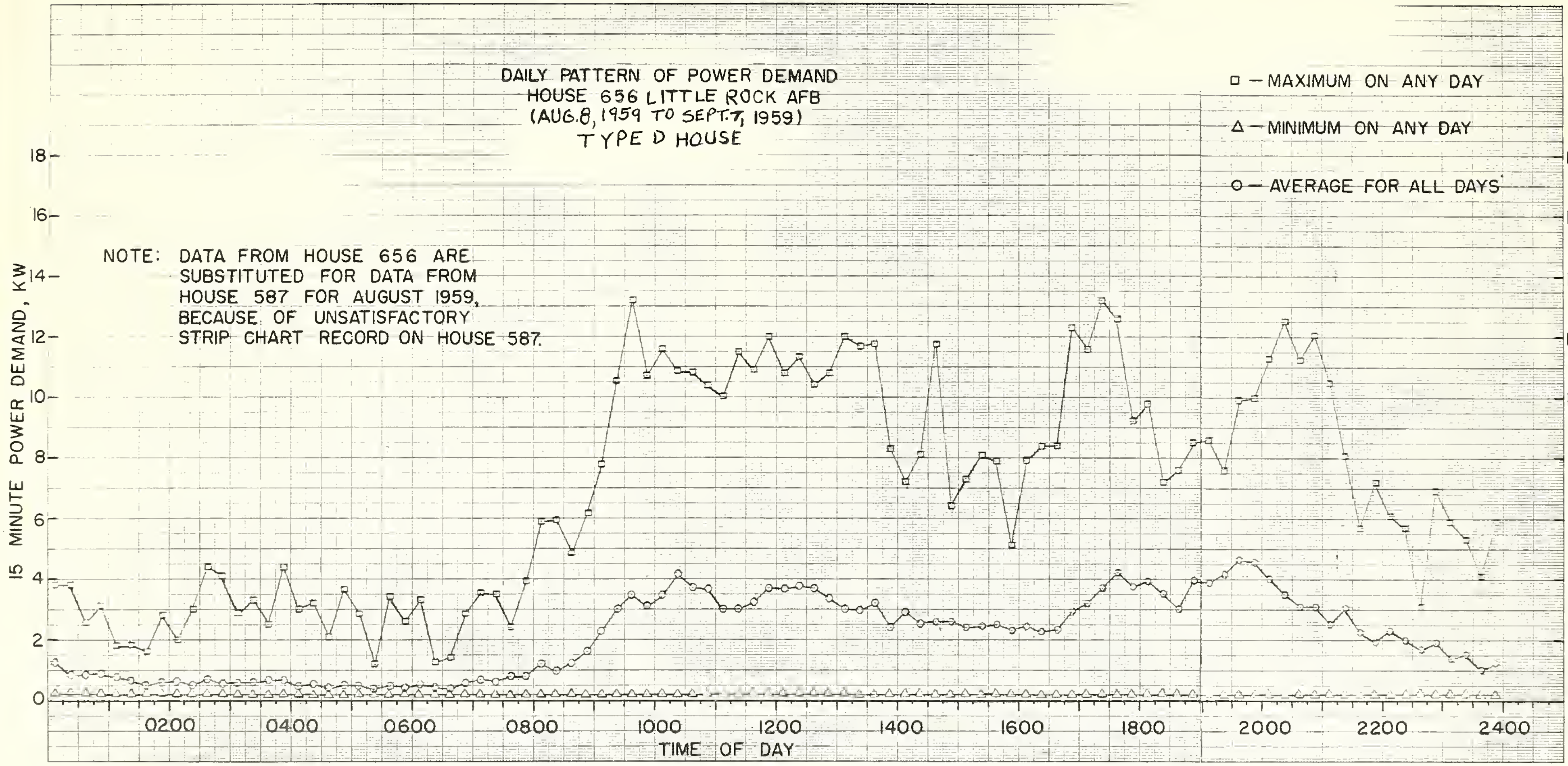
FIGURE 9


DAILY PATTERN OF POWER DEMAND
HOUSE 263 LITTLE ROCK AFB
(AUG 8, 1959 TO SEPT. 7, 1959)
TYPE A HOUSE
□ – MAXIMUM ON ANY DAY
Δ – MINIMUM ON ANY DAY
O – AVERAGE FOR ALL DAYS
NOTE: 15 – MINUTE POWER DEMAND BETWEEN AUGUST 17 AND AUGUST 30 INCLUSIVE WAS USUALLY LOWER THAN 0.2 KW AND ALWAYS LOWER THAN 4.5 KW, INDICATING LITTLE USE OF ELECTRICAL EQUIPMENT DURING THIS PERIOD. AVERAGE VALUES DETERMINED WITHOUT THE USE OF DEMAND VALUES FALLING IN THE PERIOD.
15 MINUTE POWER DEMAND, KW
0
2
4
6
8
10
12
14
16
18
0200
0400
0600
0800
1000
1200
1400
1600
1800
2000
2200
2400
TIME OF DAY
FIGURE 10



DAILY PATTERN OF POWER DEMAND
HOUSE 468, LITTLE ROCK AFB
(AUG. 8, 1959 TO SEPT. 7, 1959)
TYPE G HOUSE
— MAXIMUM ON ANY DAY
— MINIMUM ON ANY DAY
— AVERAGE FOR ALL DAYS
15 MINUTE POWER DEMAND, KW
TIME OF DAY
0200
0400
0600
0800
1000
1200
1400
1600
1800
2000
2200
2400
0
2
4
6
8
10
12
14
16
18

FIGURE 11



DAILY PATTERN OF POWER DEMAND
HOUSE 656 LITTLE ROCK AFB
(AUG.8, 1959 TO SEPT.7, 1959)
TYPE D HOUSE
□ — MAXIMUM ON ANY DAY
Δ — MINIMUM ON ANY DAY
O — AVERAGE FOR ALL DAYS
NOTE: DATA FROM HOUSE 656 ARE SUBSTITUTED FOR DATA FROM HOUSE 587 FOR AUGUST 1959, BECAUSE OF UNSATISFACTORY STRIP CHART RECORD ON HOUSE 587.
15 MINUTE POWER DEMAND, KW
0
2
4
6
8
10
12
14
16
18
0200
0400
0600
0800
1000
1200
1400
1600
1800
2000
2200
2400
TIME OF DAY

FIGURE 12

Figures 8 to 12 show that there were no high values of maximum power demand between 2200 hours in the evening and 0600 hours in the morning that approached the monthly maximum 15-minute power demand in these five houses. This indicates the high probability that the monthly maximum power demand in the summer months will also occur during the period of the day when the occupants are active.

An inspection of Figures 3 to 12 indicates that the load factor for the individual house could be increased, if some of the electrical load were shifted from the daytime hours to the night hours. Table 13 is a summary of the daily average of the energy used in five sample houses between the hours of 2300 and 0700, and between 0700 and 2300 for the months of August and January. The energy use in these two periods is also expressed as a percent of the total. It will be noted that about 12 percent of the total daily energy use occurred between the hours of 2300 and 0700 in four of the sample houses during August, and about 25 percent of the total daily energy use occurred in the same period in four of the sample houses during January. The fifth house in the group used a higher percent of the total than the others during August and a lower percent than the average during January. If the energy use were uniform, day and night, one third of the total daily use would have occurred during the 8-hour period between 2300 and 0700 hours.

Table 13

Average Day and Night Energy Use in Five Sample Houses

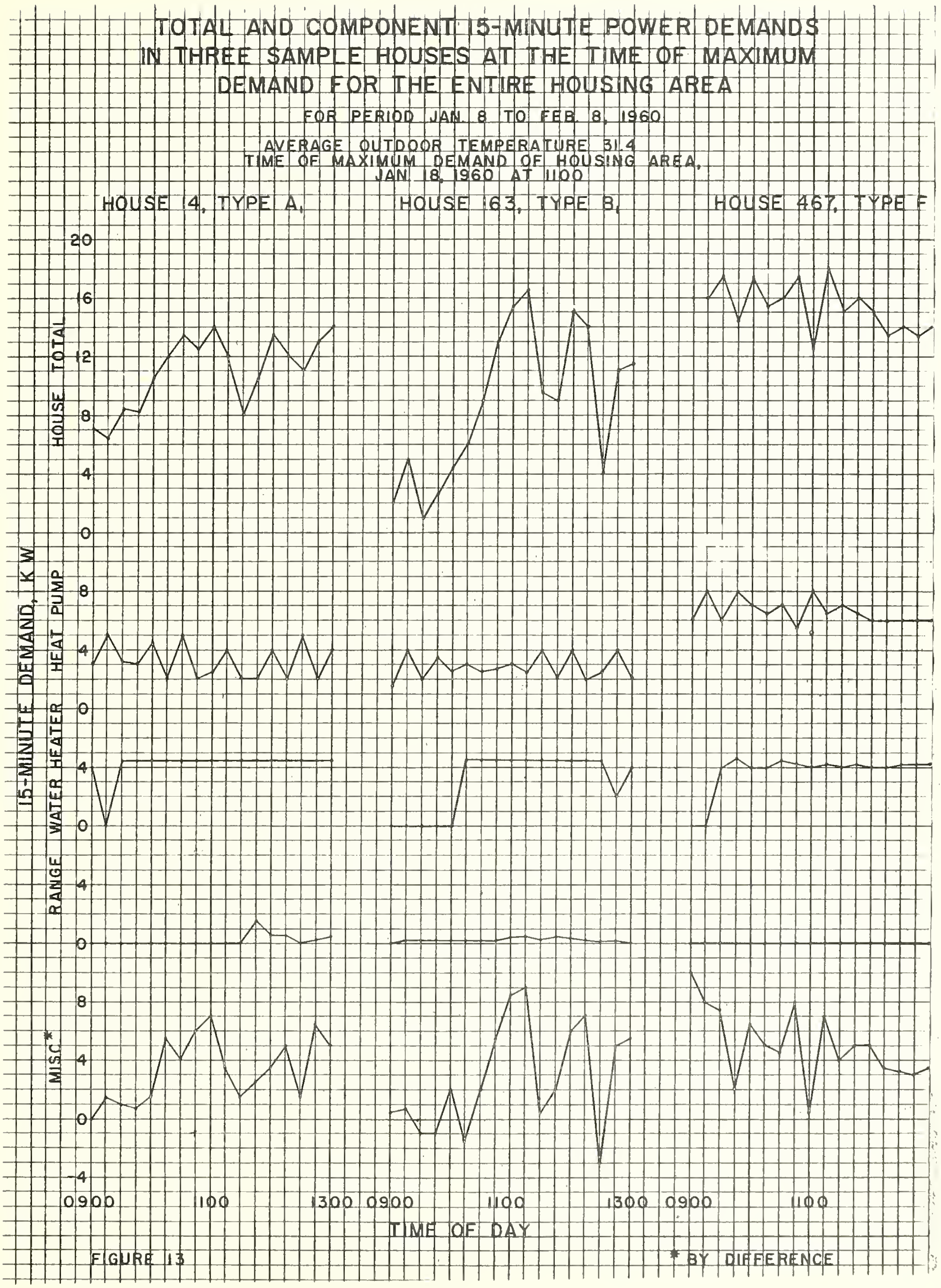
	Electric Energy Used, KWH							
	August 1959				January 1960			
House No.	2300-0700 Hours	Percent of Total	0700-2300 Hours	Percent of Total	2300-0700 Hours	Percent of Total	0700-2300 Hours	Percent of Total
14	5.8	11.4	45.1	88.6	20.0	24.1	62.9	75.9
74	9.0	12.4	63.7	87.6	10.5	25.2	31.1	74.8
263	12.7	22.4	44.0	77.6	14.7	17.7	68.3	82.3
468	9.9	11.9	73.6	88.1	38.9	27.5	102.6	72.5
587	---	---	---	---	18.4	23.9	58.6	76.1
656	5.5	10.8	45.4	89.2	---	---	---	---

3.5(c) Coincidence of Component and Total Power Demands in the Sample Houses

In order to study the contributions of the various house appliances to the maximum demands for electric power, the simultaneous demands in the 16 sample houses at the time of the maximum demand for the entire housing area were graphed for a 4-hour period, bracketing the time of the maximum value for the months of August 1959 and January 1960. The data used for these graphs were taken from the strip recorder charts of the demand meters which recorded the average power demand in kilowatts in 15-minute increments for the heat pump, the water heater, the range, and the total house load. The miscellaneous load in the house, which consisted of the lights, the toaster, the television and radio sets, the refrigerator, the clothes dryer, etc. was not metered separately, but was calculated by subtracting the sum of the range, water heater, and heat pump demands from the total house meter demand.

These graphs for houses numbered 14, 163, and 467 are shown in Figure 13 for January 1960 and in Figure 14 for August 1959. The demands of the various components of the load in each house were plotted against the same time scale such that the center of the time scale coincided with the time of the maximum power demand for the entire housing area, i.e. for 1535 houses. For the 4-hour period in January, represented in Figure 13, it will be seen that the water heater was energized continuously for several hours in each house, that the heat pump was operating intermittently on a time cycle that resulted in some power demand during every 15-minute period, that the range contributed very little to the total demand, and that the power demand of the miscellaneous devices varied widely from one 15-minute period to the next. The total power demand in house 163 varied widely during the 4-hour period ranging from 1 to 16.5 KW, and it was reasonably steady at a high level in house 467, ranging from 12.5 to 18 KW. One of the three houses had a maximum demand at 1100 hours coincident with the maximum for the entire housing area.

It should be noted that some of the graphs for miscellaneous power demand show negative values, which is a physical impossibility. It is believed that these negative values resulted from imperfect synchronization of the time clocks and the 15-minute demand intervals of the four recorders from which the miscellaneous demands were determined by calculation.


TOTAL AND COMPONENT 15-MINUTE POWER DEMANDS
IN THREE SAMPLE HOUSES AT THE TIME OF MAXIMUM
DEMAND FOR THE ENTIRE HOUSING AREA
FOR PERIOD JAN. 8 TO FEB. 8, 1960
AVERAGE OUTDOOR TEMPERATURE 31.4
TIME OF MAXIMUM DEMAND OF HOUSING AREA,
JAN 18, 1960 AT 1100
HOUSE 14, TYPE A,
HOUSE 163, TYPE B,
HOUSE 467, TYPE F
15-MINUTE DEMAND, KW
HOUSE TOTAL
HEAT PUMP
WATER HEATER
RANGE
MISC*
20
16
12
8
4
0
-4
0900
1100
1300
TIME OF DAY
* BY DIFFERENCE
FIGURE 13

TOTAL AND COMPONENT 15-MINUTE POWER DEMANDS IN THREE SAMPLE HOUSES AT THE TIME OF MAXIMUM DEMAND FOR THE ENTIRE HOUSING AREA

FOR PERIOD AUG. 7 TO SEPT. 8, 1959

AVERAGE OUTDOOR TEMPERATURE 92.2°F
TIME OF MAXIMUM DEMAND OF HOUSING AREA, AUGUST 24, 1959 AT 1145

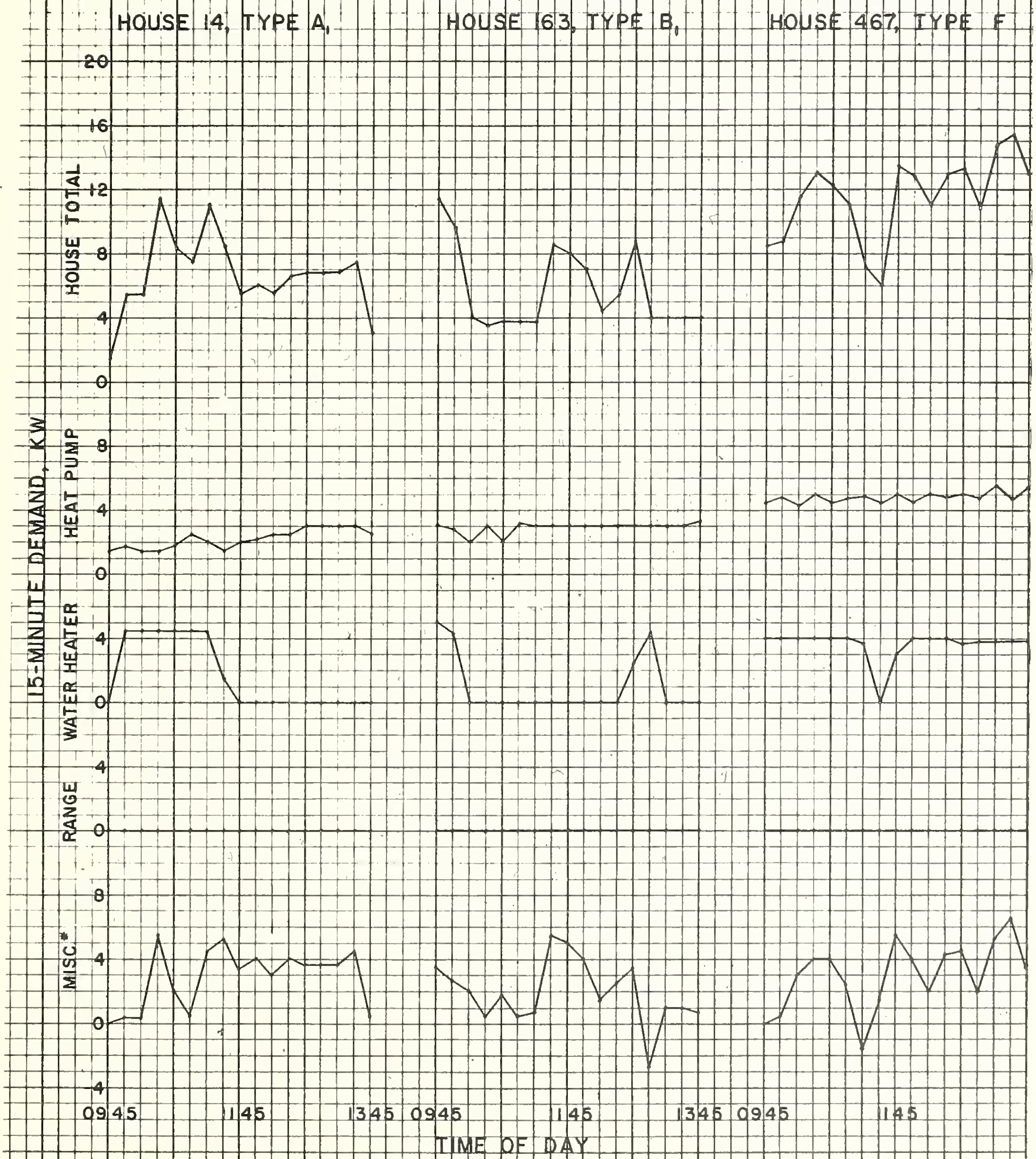


FIGURE 14

* BY DIFFERENCE

In Figure 14, the component power demands in the same houses are shown for a 4-hour period bracketing the time of the maximum demand for the entire housing area in August 1959. In each of these houses the power demand of the heat pump was fairly steady, ranging from about 2 to 6 KW for the three houses. The water heaters in two houses were energized for 1 1/2 to 3 1/2 hours, the miscellaneous devices varied in demand from 0 to 7 KW, but none of the cooking ranges were used. The maximum demand in each of these houses during the 4 hours was non-coincident with that for the entire housing area.

Figure 15 shows the demand for the house and each component averaged for all 16 of the sample houses for the same 4-hour period. This figure shows that there was sufficient diversity, or non-coincidence of high demands, within this group to produce a fairly steady total for each component and for the house total. In January there was about a 2 KW variation during the 4-hour period related to an average value of about 8 KW for the house total, and in August a variation of about 1 1/2 KW related to an average value of about 5 1/2 KW. This graph shows how the diversity in a group of houses reduces the wide variations in demand that are characteristic of a single house.

In order to study the factors that caused the monthly maximum demands in individual houses, the power demands of each component of the load and of the house as a whole were plotted for a 4-hour period bracketing the time of the monthly maximum demand for that house. Such graphs are shown for houses 14, 163, and 467 for the 1 winter month in Figure 16 and for 1 summer month in Figure 17. The time at which the monthly maximum demand occurred in each house was placed at the center of the 4-hour time scale in each graph.

In Figure 16 it will be noted that the heat pump, water heater, and miscellaneous devices contributed significantly to the maximum in each case and that the electric range contributed little or nothing in power demand. The power demand of the heat pump in houses 163 and 467 was such that use of the supplementary resistance heaters was indicated even though the outdoor temperature averaged 53°F in the case of house 163. A sustained demand in excess of 15 KW for 3 hours occurred in house 163 as a result of long steady operation of the heat pump and water heater. The high demands in the other two houses were of much shorter duration.

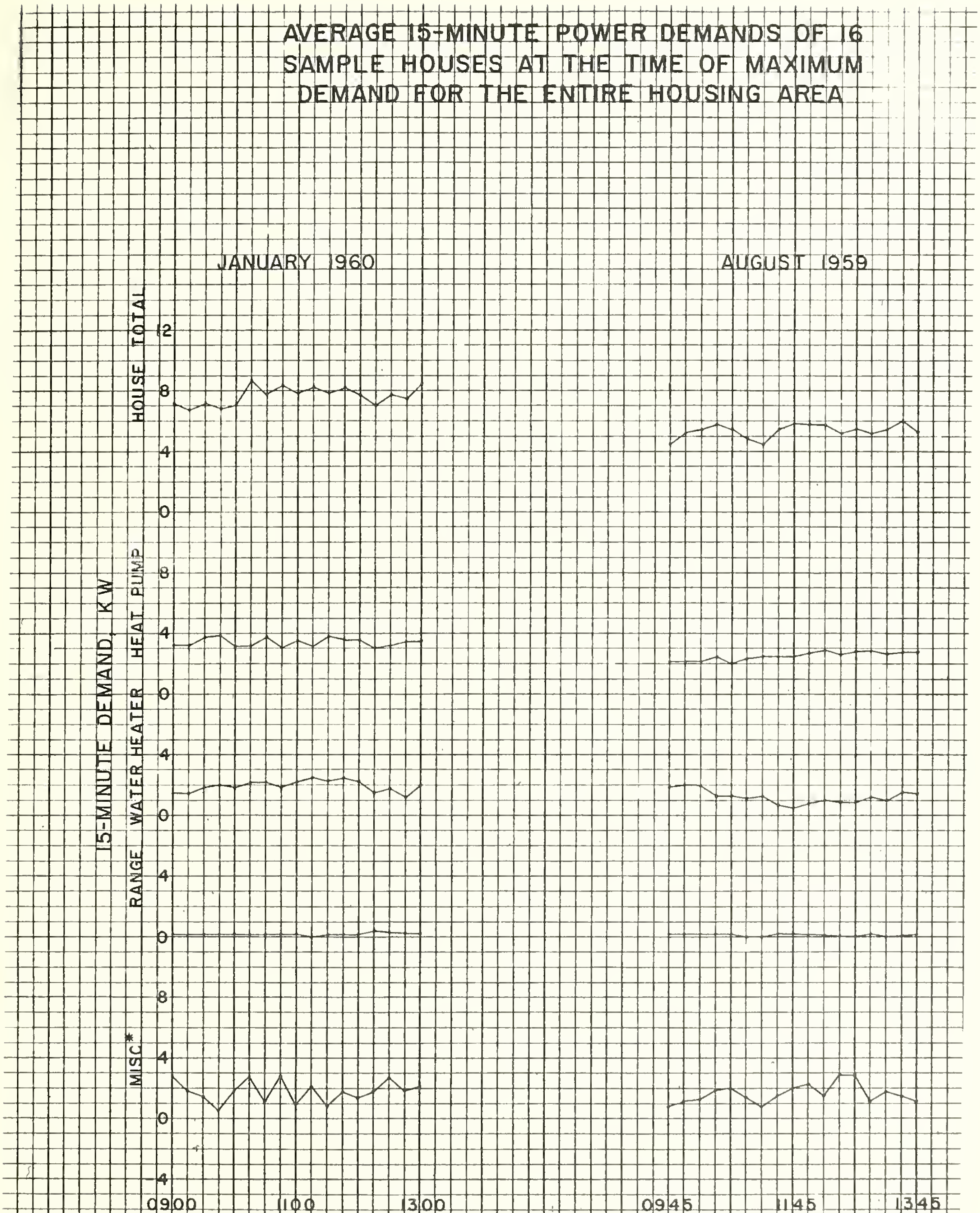
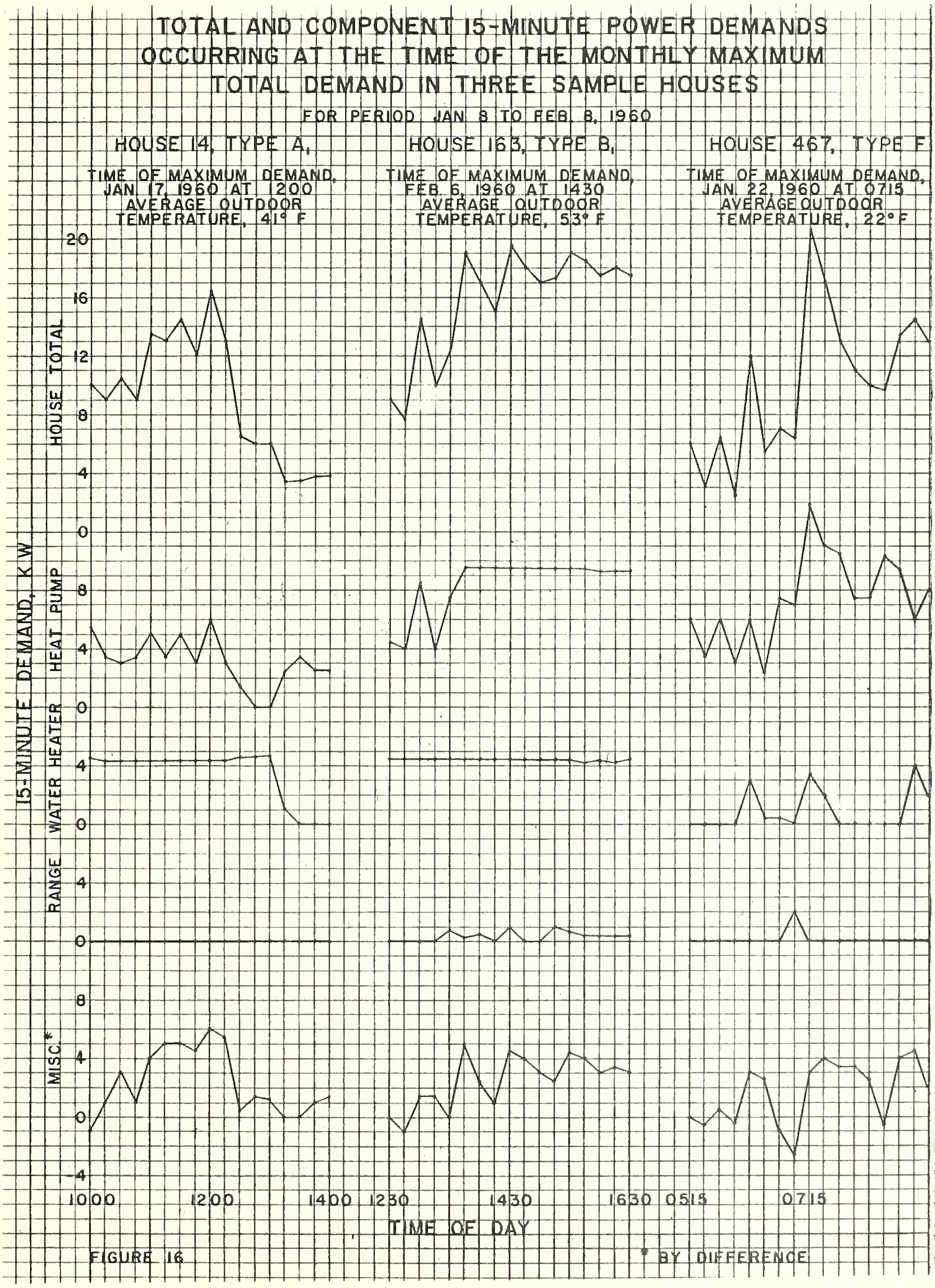


FIGURE 15

AVERAGE 15-MINUTE POWER DEMANDS OF 16 SAMPLE HOUSES AT THE TIME OF MAXIMUM DEMAND FOR THE ENTIRE HOUSING AREA

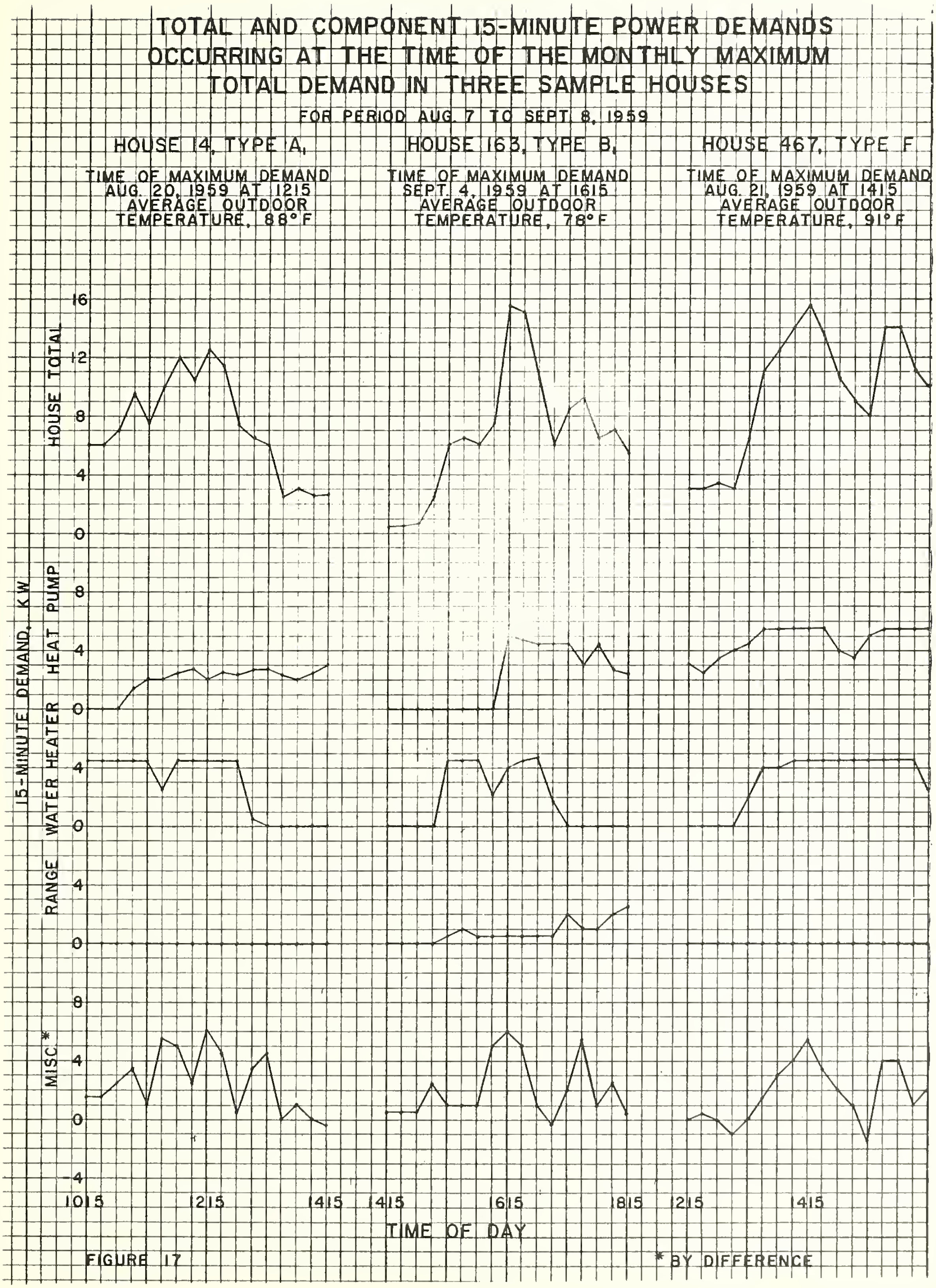

TOTAL AND COMPONENT 15-MINUTE POWER DEMANDS
OCCURRING AT THE TIME OF THE MONTHLY MAXIMUM
TOTAL DEMAND IN THREE SAMPLE HOUSES
FOR PERIOD JAN 8 TO FEB 8, 1960
HOUSE 14, TYPE A,
TIME OF MAXIMUM DEMAND, JAN 17, 1960 AT 1200
AVERAGE OUTDOOR TEMPERATURE, 41° F
HOUSE 163, TYPE B,
TIME OF MAXIMUM DEMAND, FEB 6, 1960 AT 1430
AVERAGE OUTDOOR TEMPERATURE, 53° F
HOUSE 467, TYPE F
TIME OF MAXIMUM DEMAND, JAN 22, 1960 AT 0715
AVERAGE OUTDOOR TEMPERATURE, 22° F
15-MINUTE DEMAND, KW
HOUSE TOTAL
HEAT PUMP
WATER HEATER
RANGE
MISC*
20
16
12
8
4
0
-4
1000
1200
1400
1230
1430
1630
0515
0715
TIME OF DAY
* BY DIFFERENCE
FIGURE 16

In Figure 17 the summer maxima are shown to be lower than for winter operation, but the same three components; namely, the heat pump, water heater, and miscellaneous devices were the principal contributors to the maximum power demands. The water heater provided a fixed demand whenever it was energized, winter or summer, whereas the heat pump provided a somewhat lower maximum demand in the summer because the supplementary resistance heaters would never be used.

Figure 18 shows the type of maximum demands that would have occurred if the maximum demand in all of the 15 sample houses represented by the figure had occurred coincidentally. Figure 18 shows that the average of the maxima for the 15 houses was about 17 KW whereas Figure 15 shows that the average demand of the 16 houses at the time of the maximum demand for the entire housing area was only about 8 KW. The data for house 263 was not continuous throughout the 4-hour period, and, for this reason was not included in the averages plotted in Figure 18. Figure 18 shows a high degree of coincidence between the maximum demands of each of the components of the load in the sample houses and the maximum for the house as a whole.

In order to evaluate the magnitude of the component and total power demands in each of the sample houses in a more comprehensive way than was possible,with the limited graphical presentation in Figures 13 to 18, Tables 14 to 19 were prepared to show coincident power demands in all the sample houses for 3 winter months and 3 summer months at the time of the monthly maximum power demand for the entire housing area.

Considering winter operation first, Tables 14 to 16 show that the average total house demand for the 16-house sample approximated the average for the entire housing area during two of the winter months studied; viz, January and February. Based on averages for the 16-house sample, the heat pump contributed from 45 to 63% of the total house load, the water heater from 20 to 30%, the miscellaneous devices from 11 to 21%, and the electric range from 1 to 4%. It will be noted that the heat pump in every house used some energy during the 15-minute period representing the maximum demand for each of the 3 months, and that the average power demand for the heat pump in all the sample houses ranged from 3.4 to 5.0 KW for the 3 months. The water heaters in five to eight houses, in different months, were energized


TOTAL AND COMPONENT 15-MINUTE POWER DEMANDS
OCCURRING AT THE TIME OF THE MONTHLY MAXIMUM
TOTAL DEMAND IN THREE SAMPLE HOUSES
FOR PERIOD AUG. 7 TO SEPT. 8, 1959
HOUSE 14, TYPE A,
TIME OF MAXIMUM DEMAND
AUG. 20, 1959 AT 1215
AVERAGE OUTDOOR
TEMPERATURE, 88°F
HOUSE 163, TYPE B,
TIME OF MAXIMUM DEMAND
SEPT. 4, 1959 AT 1615
AVERAGE OUTDOOR
TEMPERATURE, 78°F
HOUSE 467, TYPE F
TIME OF MAXIMUM DEMAND
AUG. 21, 1959 AT 1415
AVERAGE OUTDOOR
TEMPERATURE, 91°F
15-MINUTE DEMAND, KW
HOUSE TOTAL
HEAT PUMP
WATER HEATER
RANGE
MISC *
16
12
8
4
0
-4
1015
1215
1415
1615
1815
TIME OF DAY
FIGURE 17
* BY DIFFERENCE

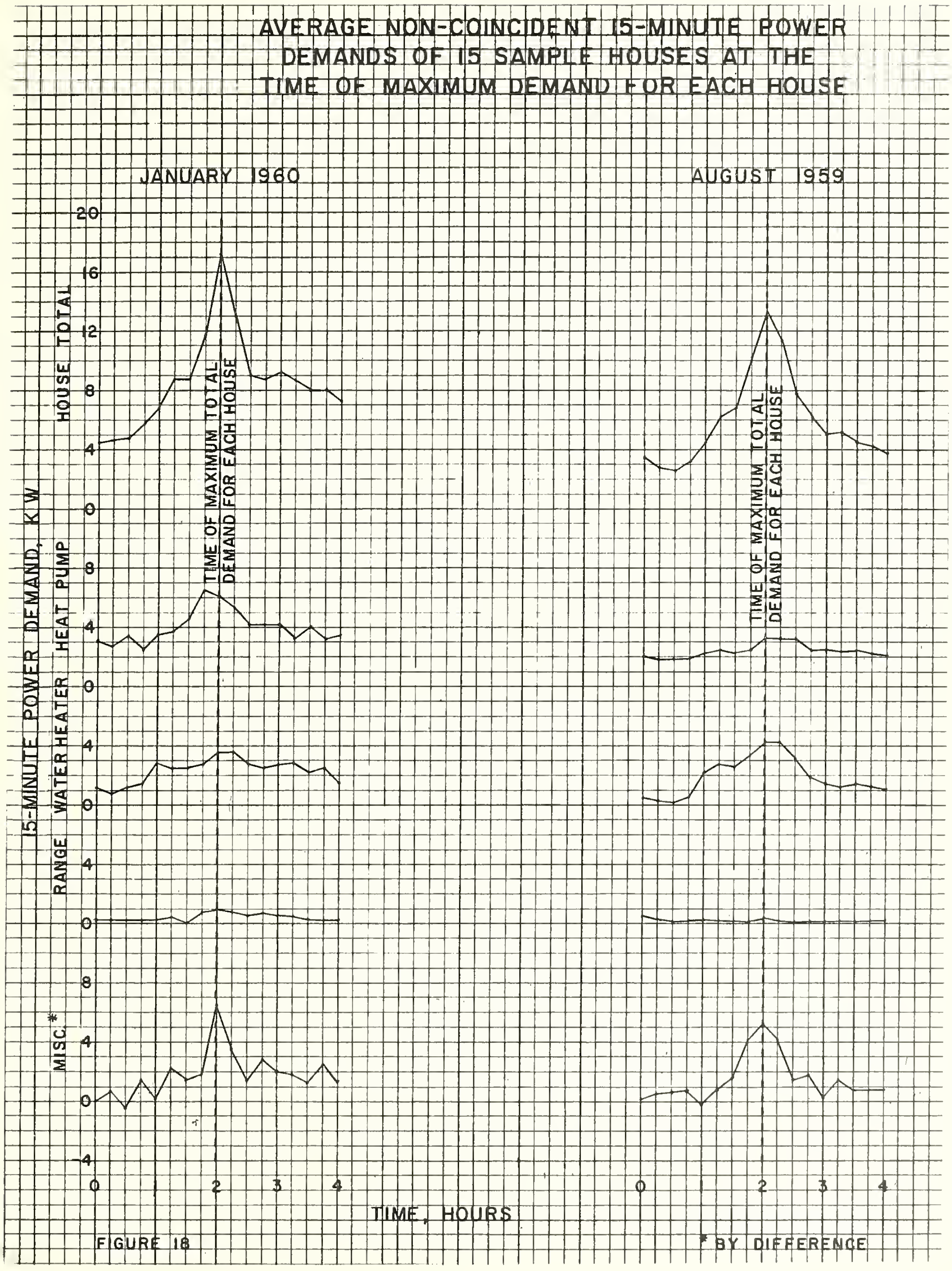

AVERAGE NON-COINCIDENT 15-MINUTE POWER DEMANDS OF 15 SAMPLE HOUSES AT THE TIME OF MAXIMUM DEMAND FOR EACH HOUSE
JANUARY 1960
AUGUST 1959
15-MINUTE POWER DEMAND, KW
HOUSE TOTAL
HEAT PUMP
WATER HEATER
RANGE
MISC.*
TIME OF MAXIMUM TOTAL DEMAND FOR EACH HOUSE
TIME OF MAXIMUM TOTAL DEMAND FOR EACH HOUSE
TIME, HOURS
* BY DIFFERENCE
FIGURE 18

Table 14

TOTAL AND COMPONENT 15-MINUTE POWER DEMANDS IN EACH SAMPLE HOUSE AT THE TIME OF MAXIMUM DEMAND FOR THE ENTIRE HOUSING AREA December 10, 1959 to January 8, 1960

Contractors House No.	Time of Housing Area Maximum Demand		Power Demand Occurring at Time of Monthly Housing Area Maximum Demand				
	Date	Time	House Total (KW)	Heat Pump (KW)	Hot Water Heater (KW)	Range (KW)	Misc.* (KW)
			2-Bedroom Houses				
14	Jan. 8, 1960	0915	9.5	3.5	4.2	0	1.8
180	"	"	5.4	5.4	0	0	0
263	"	"	3.5	2.8	0	0	0.7
301	"	"	6.0	2.4	0	0	3.6
585	"	"	4.3	2.0	0	0	2.3
843	"	"	0	0.2	0	0	-.2
			3-Bedroom Houses				
4	"	"	3.3	2.5	2.7	0	-1.9
74	"	"	Not Avail.	Not Avail.	Not Avail.	Not Avail.	Not Avail.
163	"	"	6.0	Not Avail.	0	.01	Not Avail.
172	"	"	3.5	1.2	0	0	2.3
577	"	"	6.5	5.6	0	0	0.9
587	"	"	4.8	3.6	0	0	1.2
656	"	"	2.0	0.2	4.2	0.4	-2.8
770	"	"	5.1	3.0	3.0	0	-.9
			4-Bedroom Houses				
467	"	"	12.6	7.9	4.0	0	0.7
468	"	"	8.0	6.7	0	0	1.3
Average for Sample Houses			5.4	3.4	1.1	.03	0.6
Average for 1535 Houses			7.6				

* Calculated by difference

Table 15

TOTAL AND COMPONENT 15-MINUTE POWER DEMANDS IN EACH SAMPLE HOUSE AT THE TIME OF MAXIMUM DEMAND FOR THE ENTIRE HOUSING AREA
January 8 to February 8, 1960

Contractors House No.	Time of Housing Area Maximum Demand: Date	Time	Power Demand Occurring at Time of Monthly Housing Area Maximum Demand: House Total (KW)	Heat Pump (KW)	Hot Water Heater (KW)	Range (KW)	Misc.* (KW)
			2-Bedroom Houses				
14	Jan. 18, 1960	1100	13.8	2.1	4.8	0	6.9
180	"	"	1.2	3.7	0	0	-2.5
263	"	"	7.5	3.5	4.4	0	-.4
301	"	"	8.0	4.0	0	0	4.0
585	"	"	4.3	2.2	0	0	2.1
843	"	"	4.4	4.0	0	0	0.4
			3-Bedroom Houses				
4	"	"	3.0	2.7	0	0	0.3
74	"	"	2.2	1.8	0	0	0.4
163	"	"	15.5	3.6	4.5	0.8	6.6
172	"	"	6.0	1.8	4.7	0.4	-.9
577	"	"	10.8	9.0	0	0	1.8
587	"	"	8.5	1.8	5.0	0.2	1.5
656	"	"	1.4	4.0	0	0.1	-2.7
770	"	"	7.0	1.8	4.2	0	1.0
			4-Bedroom Houses				
467	"	"	13.3	8.0	4.0	0	1.3
468	"	"	13.4	3.7	3.5	0	6.2
Average for Sample Houses			7.5	3.6	2.2	0.1	1.6
Average for 1535 Houses			8.1				

* Calculated by difference

Table 16

TOTAL AND COMPONENT 15-MINUTE POWER DEMANDS IN EACH SAMPLE HOUSE AT THE TIME OF MAXIMUM DEMAND FOR THE ENTIRE HOUSING AREA
February 8 to March 8, 1960

Contractors House No.	Time of Housing Area Maximum Demand		Power Demand Occurring at Time of Monthly Housing Area Maximum Demand				
	Date	Time	House Total (KW)	Heat Pump (KW)	Hot Water Heater (KW)	Range (KW)	Misc.* (KW)
			2-Bedroom Houses				
14	March 2, 1960	1015	6.7	5.9	0	0	1.7
180	"	"	12.7	3.5	4.7	0	4.5
263	"	"	9.5	8.5	2.4	0	-1.4
301	"	"	14.0	6.0	3.1	0	4.9
585	"	"	7.0	4.2	0	0.2	2.8
843	"	"	3.5	3.7	0	0	-.2
			3-Bedroom Houses				
4	"	"	6.0	6.1	0	0	-.1
74	"	"	1.2	3.5	0	3.0	-5.3
163	"	"	13.9	2.7	4.0	0.2	7.0
172	"	"	13.5	3.5	4.4	0	5.6
577	"	"	8.9	7.0	0	1.2	0.7
587	"	"	6.4	4.6	0	0	1.8
656	"	"	3.2	2.2	0	0	1.0
770	"	"	11.9	3.4	4.0	0.4	4.1
			4-Bedroom Houses				
467	"	"	10.9	7.9	0.2	0	2.8
468	"	"	11.4	7.8	4.4	0	-.8
Average for Sample Houses			8.7	5.0	1.7	0.3	1.8
Average for 1535 Houses			9.0				

* Calculated by difference

Table 17

TOTAL AND COMPONENT 15-MINUTE POWER DEMANDS IN EACH SAMPLE HOUSE AT THE TIME OF MAXIMUM DEMAND FOR THE ENTIRE HOUSING AREA
June 8 to July 7, 1959

Contractors House No.	Time of Housing Area Maximum Demand		Power Demand Occurring at Time of Monthly Housing Area Maximum Demand				
	Date	Time	House Total (KW)	Heat Pump (KW)	Hot Water Heater (KW)	Range (KW)	Misc.* (KW)
			2-Bedroom Houses				
14	June 29, 1959	1045	12.2	1.8	0.6	0	9.8
180	"	"	3.1	1.5	0	0	1.6
263	"	"	5.4	0	3.4	0	2.0
301	"	"	2.7	2.7	0	0	0
585	"	"	3.2	0	0	0	3.2
843	"	"	7.0	2.8	3.8	0	0.4
			3-Bedroom Houses				
4	"	"	4.2	2.1	3.6	0	-1.5
74	"	"	2.5	2.0	0	0	0.5
163	"	"	5.8	3.0	0	0	2.8
172	"	"	3.3	1.5	0.8	0.5	0.5
577	"	"	2.0	2.0	0	0.1	-0.1
587	"	"	3.2	2.1	0	0	1.1
656	"	"	0.9	1.1	0	0	-0.2
770	"	"	8.0	0	0	0	8.0
			4-Bedroom Houses				
467	"	"	9.4	4.2	3.7	0	1.5
468	"	"	9.4	Not Avail.	4.1	0	Not Avail.
Average for Sample Houses			5.1	1.8	1.3	.04	1.9
Average for 1535 Houses			4.9				

* Calculated by difference

Table 18

TOTAL AND COMPONENT 15-MINUTE POWER DEMANDS IN EACH SAMPLE HOUSE AT THE TIME OF MAXIMUM DEMAND FOR THE ENTIRE HOUSING AREA
July 7 to August 7, 1959

Contractors House No.	Time of Housing Area Maximum Demand		Power Demand Occurring at Time of Monthly Housing Area Maximum Demand				
	Date	Time	House Total (KW)	Heat Pump (KW)	Hot Water Heater (KW)	Range (KW)	Misc.* (KW)
			2-Bedroom Houses				
14	Aug. 3, 1959	1145	8.5	2.1	4.5	0	1.9
180	"	"	2.0	2.1	0	0	-0.1
263	"	"	7.8	1.9	4.9	0	1.0
301	"	"	2.8	2.1	0	0	0.7
585	"	"	2.4	2.0	0	0	0.4
843	"	"	2.0	0.8	0	0	1.2
			3-Bedroom Houses				
4	"	"	3.0	2.0	0	0	1.0
74	"	"	8.2	2.4	0.7	0.4	4.7
163	"	"	4.5	3.0	0	0	1.5
172	"	"	2.5	3.0	0	0.5	-1.0
577	"	"	2.8	2.7	0	0	0.1
587	"	"	3.4	2.4	3.0	0.2	-2.2
656	"	"	0.9	2.3	0	0	-1.4
770	"	"	3.4	0	0	0	3.4
			4-Bedroom Houses				
467	"	"	5.5	3.8	0	0	1.7
468	"	"	4.8	4.4	0	0	0.4
Average for Sample Houses			4.0	2.3	0.8	0.1	0.8
Average for 1535 Houses			4.8				

* Calculated by difference

Table 19

TOTAL AND COMPONENT 15-MINUTE POWER DEMANDS IN EACH SAMPLE HOUSE AT THE TIME OF MAXIMUM DEMAND FOR THE ENTIRE HOUSING AREA
August 7 to September 8, 1959

Contractors House No.	Time of Housing Area Maximum Demand Date	Time	Power Demand Occurring at Time of Monthly Housing Area Maximum Demand House Total (KW)	Heat Pump (KW)	Hot Water Heater (KW)	Range (KW)	Misc.* (KW)
			2-Bedroom Houses				
14	Aug. 24, 1959	1145	5.7	2.0	0	0	3.7
180	"	"	1.6	2.0	0	0	-.4
263	"	"	3.3	0	0	0	3.3
301	"	"	5.3	3.0	0	0	2.3
585	"	"	0.4	0	0	0	.4
843	"	"	2.6	2.0	0	.4	.2
			3-Bedroom Houses				
4	"	"	2.8	2.3	0	0	.5
74	"	"	11.4	2.8	0	1.0	7.6
163	"	"	8.0	3.0	0	0	5.0
172	"	"	9.4	2.0	2.0	0.5	4.9
577	"	"	4.6	2.4	2.1		0.1
587	"	"	--	--	--	--	--
656	"	"	6.7	3.4	0	0.2	3.1
770	"	"	3.2	2.0	0	0	1.2
			4-Bedroom Houses				
467	"	"	13.5	5.2	3.2	0	5.1
468	"	"	6.3	0.7	0	1.0	4.6
Average for Sample Houses			5.7	2.2	0.5	0.2	2.8
Average for 1535 Houses			4.9				

* Calculated from difference

at the time of the maximum demand, and in only a few cases were the electric ranges using a significant amount of energy. Tables 14 to 16 show that the maximum demand for the entire housing area occurred between 0900 and 1100 hours for the 3 winter months represented.

Tables 17 to 19 show that in the summer months of June to August 1959 the average total house demand for the 16-house sample exceeded the average for the entire housing area by amounts up to 16% for two of the three months and was less than the average for the entire housing area by 17% in July. Based on averages for the 16 sample houses, the heat pump contributed from 33 to 58% of the total house load, the water heater from 9 to 26%, the miscellaneous devices from 20 to 54%, and the electric range from 3 to 8%. The tables show that the heat pump in a large majority of the houses operated during a part of the 15-minute period representing the maximum demand, water heaters in 3 to 7 houses were energized at the time of maximum demand, and very few of the electric ranges contributed a significant amount to the total load. Tables 17 to 19 show that the maximum demand for the entire housing area occurred between 1000 hours and noon for the 3 summer months studied.

The negative values that appear for the power demand of the miscellaneous devices in Tables 14 to 19 indicate that the demand periods were not perfectly synchronized and that the reported demand values do not represent simultaneous occurrences in some cases. However, the demands reported for the heat pump, water heater, electric range, and the house total are recorded values that certainly occurred within a few minutes of each other.

The non-coincident monthly maximum demands in each of the 16 sample houses and the component loads that made up the maximum in each house were summarized in Tables 20 to 22 for 3 winter months and in Tables 23 to 25 for 3 summer months. In the winter months, the average of these maximum values ranged from 17.0 to 18.2 KW, of which about 35 percent was power used by the heat pump, about 20 percent was used by the water heater, about 5 percent was used by the electric range, and about 40 percent was used by the miscellaneous devices. Tables 20 to 22 show that 75 to 100 percent of the heat pumps, 81 to 94 percent of the hot water heaters, and 19 to 25 percent of the electric ranges in the 16 sample houses were using more than 1 KW of electric power

at the time of the maximum winter power demand. At the same time, the miscellaneous devices in 87 to 94 percent of the sample houses were using more than 1 KW of electric power.

For the 3 summer months, the average of the maximum monthly power demands of the 16 sample houses ranged from 13.8 to 13.9 KW, of which about 23 percent was power used by the heat pump, about 26 percent was used by the water heater, about 3 percent was used by the electric range, and about 45 percent was used by the miscellaneous devices. Tables 23 to 25 show that 87 to 94 percent of the heat pumps, 81 to 87 percent of the water heaters, and 6 to 13 percent of the electric ranges in the 16 sample houses were using more than 1 KW of electric power at the time of the maximum summer power demand. At the same time the miscellaneous devices in 87 to 100 percent of the sample houses were using more than 1 KW of electric power.

The power demand data shown in Tables 20 to 25 show that the miscellaneous devices made a larger contribution to the monthly maximum demand in the sample houses on the average than any of the other components of the load during both winter and summer conditions.

Tables 20 to 25 show that maximum demands in the individual houses occurred on different days and at different times of the day in most cases, both winter and summer. A study of the demand charts and the charts from the outdoor temperature recorders also showed that the maximum demands in the individual houses occurred at various outdoor temperatures. In the month of January 1960, the outdoor temperatures, at the time of the monthly maximum demands in the 16 sample houses, ranged from 21°F to 58°F, distributed as follows:

Outdoor Temperature Range, °F	Number of Cases
20 to 30	2
30 to 40	10
40 to 50	2
Above 50	2

In the month of August 1959, the outdoor temperatures, at the time of the monthly maximum demands in the 16 sample houses, ranged from 78°F to 93°F, distributed as follows:

Table 20

TOTAL AND COMPONENT 15-MINUTE POWER DEMAND OCCURRING AT THE TIME OF THE MONTHLY MAXIMUM TOTAL DEMAND IN EACH SAMPLE HOUSE
December 10, 1959 to January 8, 1960

Contractors House No.	Time of Maximum Total Demand for House: Date	Time of Maximum Total Demand for House: Time	Maximum Total Demand for House (KW)	Coincident Component Demand: Heat Pump (KW)	Hot Water Heater (KW)	Range (KW)	Misc.* (KW)
			2-Bedroom Houses				
14	Jan. 1, 1960	1130	16.8	5.8	4.5	0.1	6.4
180	Jan. 7, 1960	1730	16.7	4.0	4.5	2.5	5.7
263	Jan. 6, 1960	1230	17.1	7.2	5.0	0	4.9
301	Jan. 1, 1960	0845	17.6	7.0	4.2	0	6.4
585	Dec. 16, 1959	0600	18.8	7.9	4.4	0.7	5.8
843	Jan. 6, 1960	1145	11.6	8.4	3.7	0	-.5
			3-Bedroom Houses				
4	Jan. 8, 1960	0730	16.6	7.6	4.5	3.8	0.7
74	Dec. 18, 1959	0800	12.0	6.0	0	2.9	3.1
163	Jan. 6, 1960	1300	20.8	4.4	2.7	0.1	13.6
172	Jan. 7, 1960	1145	18.2	7.0	4.8	0.4	6.0
577	Jan. 8, 1960	0700	19.2	9.0	3.5	0	6.7
587	Dec. 30, 1959	1015	15.9	2.3	4.9	0	8.7
656	Jan. 5, 1960	1045	17.0	4.6	4.4	0.1	7.9
770	Dec. 30, 1959	2015	16.2	9.1	4.4	0.5	2.2
			4-Bedroom Houses				
467	Dec. 28, 1959	0830	17.9	9.4	4.2	0.2	4.1
468	Dec. 28, 1959	1045	17.9	4.5	2.9	0	10.5
Average for 16 Houses			17.0	6.5	3.9	0.7	5.8

* Calculated from difference

Table 21

TOTAL AND COMPONENT 15-MINUTE POWER DEMAND OCCURRING AT THE TIME OF THE MONTHLY MAXIMUM TOTAL DEMAND IN EACH SAMPLE HOUSE
January 8 to February 8, 1960

Contractors House No.	Time of Maximum Total Demand for House		Maximum Total Demand for House (KW)	Coincident Component Demand			
	Date	Time		Heat Pump (KW)	Hot Water Heater (KW)	Range (KW)	Misc.* (KW)
			2-Bedroom Houses				
14	Jan. 17, 1960	1215	16.1	3.0	4.5	0	8.6
180	Jan. 20, 1960	1330	17.9	0	4.5	1.0	12.4
263	Feb. 8, 1960	1245	18.0	Not Avail.	Not Avail.	Not Avail.	Not Avail.
301	Jan. 29, 1960	0915	16.9	2.5	4.2	0	10.2
585	Jan. 20, 1960	1715	18.8	6.0	4.8	0.9	7.1
843	Jan. 25, 1960	1000	16.2	8.5	0	0	7.7
			3-Bedroom Houses				
4	Jan. 31, 1960	0900	17.6	1.0	2.4	4.0	10.2
74	Feb. 5, 1960	1815	12.4	4.0	3.0	3.0	2.4
163	Feb. 6, 1960	1430	19.6	9.2	4.5	1.0	4.9
172	Jan. 16, 1960	1815	18.6	5.9	4.5	4.0	4.2
577	Jan. 17, 1960	0845	19.4	4.0	2.0	-2.0	11.4
587	Feb. 6, 1960	0900	16.2	10.0	4.0	1.0	1.2
656	Jan. 25, 1960	0915	15.8	1.0	4.5	0.2	10.1
770	Jan. 18, 1960	1300	14.6	4.0	4.0	0.2	6.4
			4-Bedroom Houses				
467	Jan. 22, 1960	0715	20.8	13.9	3.8	0	3.1
468	Jan. 21, 1960	0730	19.4	14.0	2.8	0	2.6
Average for 16 Houses			17.4	5.8	3.6	1.2	6.8

* Calculated from difference

Table 22

TOTAL AND COMPONENT 15-MINUTE POWER DEMAND OCCURRING AT THE TIME OF THE MONTHLY MAXIMUM TOTAL DEMAND IN EACH SAMPLE HOUSE
February 8 to March 8, 1960

Contractors House No.	Time of Maximum Total Demand for House: Date	Time	Maximum Total Demand for House (KW)	Coincident Component Demand: Heat Pump (KW)	Hot Water Heater (KW)	Range (KW)	Misc.* (KW)
			2-Bedroom Houses				
14	Mar. 3, 1960	1145	16.7	5.7	4.6	0	6.4
180	Feb. 27, 1960	1030	17.7	7.4	4.5	0	5.8
263	Feb. 19, 1960	1330	18.1	5.5	5.0	0	7.6
301	Feb. 15, 1960	0815	Not Avail.	Not Avail.	Not Avail.	Not Avail.	Not Avail.
585	Feb. 17, 1960	0545	19.1	5.6	4.4	0	9.1
843	Feb. 26, 1960	0700	17.6	8.1	3.4	3.1	3.0
			3-Bedroom Houses				
4	Mar. 3, 1960	0730	17.6	2.0	4.7	4.4	6.5
74	Feb. 14, 1960	2145	17.2	13.8	3.0	3.8	-3.4
163	Mar. 3, 1960	1115	18.2	0.4	3.5	0.1	14.2
172	Mar. 3, 1960	1145	17.6	0	4.7	0	12.9
577	Feb. 29, 1960	0715	20.1	10.2	4.5	Not Avail.	5.4
587	Mar. 2, 1960	0900	17.2	10.4	0	0	6.8
656	Mar. 6, 1960	1645	17.8	0	4.5	0.4	12.9
770	Feb. 24, 1960	1000	16.8	3.3	0	0.4	13.1
			4-Bedroom Houses				
467	Feb. 29, 1960	0815	20.8	10.8	4.3	0	5.7
468	Mar. 1, 1960	1115	20.2	7.8	3.0	0	9.4
Average for 16 Houses			18.2	6.1	3.6	0.9	7.7

* Calculated from difference

Table 23

TOTAL AND COMPONENT 15-MINUTE POWER DEMAND OCCURRING AT THE TIME OF THE MONTHLY MAXIMUM TOTAL DEMAND IN EACH SAMPLE HOUSE
June 8 to July 7, 1959

Contractors House No.	Time of Maximum Total Demand for House: Date	Time of Maximum Total Demand for House: Time	Maximum Total Demand for House (KW)	Coincident Component Demand: Heat Pump (KW)	Coincident Component Demand: Hot Water Heater (KW)	Coincident Component Demand: Range (KW)	Coincident Component Demand: Misc.* (KW)
			2-Bedroom Houses				
14	June 21, 1959	1430	13.9	3.1	0.6	0.4	9.8
180	July 4, 1959	1230	14.7	2.8	4.9	1.8	5.2
263	June 26, 1959	1100	13.4	2.8	4.4	0	6.2
301	July 1, 1959	1630	13.4	3.1	4.5	0	5.8
585	June 10, 1959	1015	13.4	3.0	5.0	0	5.4
843	June 22, 1959	1030	12.2	2.8	4.2	0.2	5.0
			3-Bedroom Houses				
4	June 29, 1959	0830	11.8	0.9	4.8	0	6.1
74	July 1, 1959	2000	13.4	13.2	3.0	0	-2.8
163	June 8, 1959	1145	15.1	4.8	5.0	0.5	4.8
172	July 4, 1959	2045	14.4	3.0	4.5	0	6.9
577	June 22, 1959	2030	12.5	1.6	3.3	0	7.6
587	July 6, 1959	1130	14.1	2.6	4.7	0.9	5.9
656	July 5, 1959	1715	13.0	1.3	2.0	0	9.7
770	June 8, 1959	2100	14.2	1.1	4.5	0	8.6
			4-Bedroom Houses				
467	June 28, 1959	1430	15.4	5.4	0	0	10.0
468	June 27, 1959	1215	15.9	Not Avail.	0	0.5	Not Avail.
Average for 16 Houses			13.8	3.4	3.5	0.3	5.9

* Calculated from difference

Table 24

TOTAL AND COMPONENT 15-MINUTE POWER DEMAND OCCURRING AT THE TIME OF THE MONTHLY MAXIMUM TOTAL DEMAND IN EACH SAMPLE HOUSE
July 7 to August 7, 1959

Contractors House No.	Time of Maximum Total Demand for House: Date	Time	Maximum Total Demand for House (KW)	Coincident Component Demand: Heat Pump (KW)	Hot Water Heater (KW)	Range (KW)	Misc.* (KW)
			2-Bedroom Houses				
14	July 20, 1959	1145	12.7	2.5	4.2	2.4	3.6
180	Aug. 5, 1959	0900	11.7	1.0	Not Avail.	0	Not Avail.
263	Aug. 3, 1959	1230	14.0	2.7	4.8	0	6.5
301	July 20, 1959	0845	13.8	3.0	4.8	0	6.0
585	Aug. 6, 1959	1800	14.9	2.0	2.4	3.2	7.3
843	July 17, 1959	1830	11.7	2.0	2.8	0.5	6.4
			3-Bedroom Houses				
4	July 10, 1959	1600	13.7	3.7	0	0	10.0
74	Aug. 1, 1959	1145	13.2	3.2	4.2	0	5.8
163	July 11, 1959	1445	17.7	2.8	0	0.5	14.4
172	Aug. 5, 1959	1145	14.4	2.4	4.2	- 1.0	6.8
577	July 25, 1959	1500	14.0	2.5	4.6	0.4	7.5
587	July 8, 1959	1900	13.2	6.5	4.6	0	2.1
656	July 9, 1959	1145	13.6	0.6	4.4	0	8.6
770	Aug. 6, 1959	1330	12.6	2.9	4.0	0	5.7
			4-Bedroom Houses				
467	July 16, 1959	1130	13.6	2.5	4.0	0.6	6.5
468	Aug. 6, 1959	1630	16.8	6.0	4.0	0.6	6.2
Average for 16 Houses			13.9	2.9	3.3	0.6	6.5

* Calculated from difference

Table 25

TOTAL AND COMPONENT 15-MINUTE POWER DEMAND OCCURRING AT THE TIME OF THE MONTHLY MAXIMUM TOTAL DEMAND IN EACH SAMPLE HOUSE
August 7 to September 8, 1959

Contractors House No.	Time of Maximum Total Demand for House: Date	Time of Maximum Total Demand for House: Time	Maximum Total Demand for House (KW)	Coincident Component Demand: Heat Pump (KW)	Coincident Component Demand: Hot Water Heater (KW)	Coincident Component Demand: Range (KW)	Coincident Component Demand: Misc.* (KW)
			2-Bedroom Houses				
14	Aug. 20, 1959	1215	12.8	2.0	4.5	0	6.3
180	Sep. 2, 1959	1315	13.4	2.8	4.4	1.4	4.8
263	Sep. 7, 1959	1200	13.5	3.0	4.4	0	6.1
301	Aug. 16, 1959	1030	14.0	3.0	4.5	0	6.5
585	Aug. 25, 1959	1745	13.7	5.0	4.6	2.7	1.4
843	Aug. 28, 1959	1245	11.5	0	0.5	0	11.0
			3-Bedroom Houses				
4	Sep. 8, 1959	0930	15.6	2.8	0.8	0	12.0
74	Aug. 23, 1959	1400	15.3	4.5	4.4	0	6.5
163	Sep. 4, 1959	1615	15.6	5.0	4.2	0.5	5.9
172	Aug. 17, 1959	1845	12.8	2.0	4.5	1.0	5.3
577	Aug. 20, 1959	2015	13.6	2.2	4.6	0.5	6.3
587	Aug. 10, 1959	1130	12.4	2.1	4.7	0.5	5.1
656	Sep. 1, 1959	0945	13.4	3.0	4.4	0	6.0
770	Aug. 17, 1959	0645	13.2	1.2	4.2	0	7.8
			4-Bedroom Houses				
467	Aug. 21, 1959	1415	15.2	5.5	4.3	0	5.4
468	Aug. 29, 1959	1415	16.8	7.2	4.4	0	5.2
Average for 16 Houses			13.9	3.2	4.0	0.4	6.4

* Calculated from difference

Outdoor Temperature Range, °F	Number of Cases
Below 70	None
70 to 80	1
80 to 90	13
90 to 100	2
Over 100	None

These results indicate that the maximum demands in individual houses during winter and summer were not directly related to the magnitude of the heating and cooling loads.

Tables 26 to 31 show the non-coincident monthly maximum power demand for each of the 16 sample houses and the monthly maximum power demand of each of the four components comprising the total house load. The monthly maximum power demands of the components did not necessarily coincide with the monthly maximums for the house as a whole. The degree of coincidence between the monthly component maximums and the monthly maximum for the entire house is shown as a coincidence factor in these tables. For the purpose of these tables, the coincidence factor is defined as the ratio of the maximum power demand of the house as a unit to the sum of the maximum power demands of the appliance components in the house over a period of a month.

Tables 26 to 28, for the 3 winter months used for analysis, show that the maximum power demands for the various components were fairly consistent from month to month when comparing averages for all of the sample houses. The maximum power demands for the heat pump ranged from 5.6 to 14.8 KW in different houses with the 3-month average for all houses being 9.2 KW. Individual houses cannot reasonably be compared because different house types were equipped with different amounts of supplementary resistance heating, and houses 467 and 468 were equipped with two heat pumps whereas the others in the sample contained only one. The maximum power demand of the water heaters varied from 4.5 KW to 5.4 KW, probably due to voltage variations at different houses. The maximum power demands of the electric ranges varied widely depending on the habits of the individual occupant. Probably none of the recorded maximum power demands represent the full load demand of the range. The miscellaneous devices provided the second largest maximum power demand on the average. The biggest single electrical load included in the miscellaneous group was the clothes dryer, whose power consumption was about 5 KW. Other significant loads in the miscellaneous group were the resistance heater in the bathroom, the washing machine, and such appliances as electric irons and toasters.

Table 26

NON-COINCIDENT TOTAL AND COMPONENT 15-MINUTE MAXIMUM POWER DEMANDS OCCURRING AT ANYTIME DURING THE MONTH IN EACH SAMPLE HOUSE
December 10, 1959 to January 8, 1960

Contractors House No.	Time of Maximum Total Demand for House		Maximum Non-Coincident Power Demands for Month					Monthly Coincidence Factor for the House
	Date	Time	House (KW)	Heat Pump (KW)	Hot Water Heater (KW)	Range (KW)	Misc. (KW)	
			2-Bedroom Houses					
14	Jan. 1, 1960	1130	16.8	6.6	4.8	3.7	6.4	.78
180	Jan. 7, 1960	1730	16.7	7.7	4.8	4.0	5.2	.77
263	Jan. 6, 1960	1230	17.1	8.6	5.2	1.0	11.7	.65
301	Jan. 1, 1960	0845	17.6	7.5	4.5	7.6	7.6	.65
585	Dec. 16, 1959	0600	18.8	8.4	5.0	3.7	7.4	.77
843	Jan. 6, 1960	1145	11.6	8.6	5.2	0	5.0	.62
			3-Bedroom Houses					
4	Jan. 8, 1960	0730	16.6	8.4	4.8	5.1	5.1	.71
74	Dec. 18, 1959	0800	12.0	8.1	4.6	6.2	3.1	.55
163	Jan. 6, 1960	1300	20.8	11.2	5.2	4.3	4.7	.82
172	Jan. 7, 1960	1145	18.2	9.3	5.0	4.5	6.1	.73
577	Jan. 8, 1960	0700	19.2	10.3	5.0	5.6	5.8	.72
587	Dec. 30, 1959	1015	15.9	10.2	5.1	4.2	6.9	.60
656	Jan. 5, 1960	1045	17.0	9.9	4.8	4.1	9.9	.59
770	Dec. 30, 1959	0815	16.2	9.8	4.8	3.6	6.7	.65
			4-Bedroom Houses					
467	Dec. 28, 1959	0830	17.9	12.2	4.6	3.0	5.0	.72
468	Dec. 28, 1959	1045	17.9	14.0	4.8	4.3	5.7	.59
Average for 16 Houses			17.0	9.4	4.9	4.1	6.4	.68

Table 27

NON-COINCIDENT TOTAL AND COMPONENT 15-MINUTE MAXIMUM POWER DEMANDS OCCURRING AT ANYTIME DURING THE MONTH IN EACH SAMPLE HOUSE
January 8 to February 8, 1960

Contractors House No.	Time of Maximum Total Demand for House		Maximum Non-Coincident Power Demands for Month					Monthly Coincidence Factor for the House
	Date	Time	House (KW)	Heat Pump (KW)	Hot Water Heater (KW)	Range (KW)	Misc. (KW)	
			2-Bedroom Houses					
14	Jan. 17, 1960	1215	16.1	6.8	4.8	5.7	8.2	.63
180	Jan. 20, 1960	1330	17.9	7.7	4.8	2.8	8.5	.75
263	Feb. 8, 1960	1145	14.8	8.7	5.2	0.6	8.8	.77
301	Jan. 29, 1960	0915	16.9	7.4	4.6	4.0	7.2	.73
585	Jan. 20, 1960	1715	18.8	8.4	4.9	3.9	6.0	.81
843	Jan. 25, 1960	1000	16.2	8.3	5.4	4.2	6.2	.67
			3-Bedroom Houses					
4	Jan. 31, 1960	0900	17.6	8.4	4.8	6.3	6.5	.68
74	Feb. 5, 1960	1815	12.4	7.6	4.5	5.7	5.2	.54
163	Feb. 6, 1960	1430	19.6	10.8	5.2	4.9	8.2	.67
172	Jan. 16, 1960	1815	18.6	6.6	5.0	5.4	6.0	.81
577	Jan. 17, 1960	0845	19.4	10.5	4.9	5.0	8.4	.67
587	Feb. 6, 1960	0900	16.2	10.1	5.1	4.4	5.4	.65
656	Jan. 25, 1960	0915	15.8	9.7	4.8	4.3	7.4	.60
770	Jan. 18, 1960	1300	14.6	10.1	4.6	3.6	7.5	.57
			4-Bedroom Houses					
467	Jan. 22, 1960	0715	20.8	14.0	4.7	3.0	5.8	.76
468	Jan. 21, 1960	0730	19.4	14.2	4.7	4.0	4.5	.71
Average for 16 Houses			17.2	9.3	4.9	4.2	6.9	.69

Table 28

NON-COINCIDENT TOTAL AND COMPONENT 15-MINUTE MAXIMUM POWER DEMANDS OCCURRING AT ANYTIME DURING THE MONTH IN EACH SAMPLE HOUSE
February 8 to March 8, 1960

Contractors House No.	Time of Maximum Total Demand for House: Date	Time of Maximum Total Demand for House: Time	Maximum Non-Coincident Power Demands for Month: House (KW)	Heat Pump (KW)	Hot Water Heater (KW)	Range (KW)	Misc. (KW)	Monthly Coincidence Factor for the House
			2-Bedroom Houses					
14	Mar. 3, 1960	1145	16.7	6.6	4.7	3.1	5.7	.83
180	Feb. 27, 1960	1030	17.7	7.8	4.7	4.1	5.3	.81
263	Feb. 19, 1960	1330	18.1	8.6	5.3	0.7	9.0	.77
301	Feb. 15, 1960	0815	17.6	7.4	4.4	3.8	5.6	.83
585	Feb. 17, 1960	0545	19.1	8.1	5.0	5.0	4.2	.87
843	Feb. 26, 1960	0700	17.6	8.6	5.4	4.3	5.2	.75
			3-Bedroom Houses					
4	Mar. 3, 1960	0730	17.6	7.4	4.8	5.5	9.4	.65
74	Feb. 14, 1960	2145	17.2	7.5	4.5	5.9	8.8	.64
163	Mar. 3, 1960	1115	18.2	5.6	4.6	5.3	9.1	.74
172	Mar. 3, 1960	1145	17.6	9.7	5.0	4.6	5.7	.70
577	Feb. 29, 1960	0715	20.1	10.6	4.9	5.8	5.1	.76
587	Mar. 2, 1960	0900	17.2	10.5	5.2	2.8	7.0	.67
656	Mar. 6, 1960	1645	17.8	9.4	4.7	4.4	7.9	.67
770	Feb. 24, 1960	1000	16.8	9.5	4.5	3.6	8.2	.65
			4-Bedroom Houses					
467	Feb. 29, 1960	0815	20.8	14.8	4.7	4.0	9.8	.62
468	Mar. 1, 1960	1115	20.2	8.2	4.7	6.7	9.2	.70
Average for 16 Houses			18.1	8.8	4.8	4.4	7.2	.73

Table 29

NON-COINCIDENT TOTAL AND COMPONENT 15-MINUTE MAXIMUM POWER DEMANDS OCCURRING AT ANYTIME DURING THE MONTH IN EACH SAMPLE HOUSE
June 8 to July 7, 1959

Contractors House No.	Time of Maximum Total Demand for House: Date	Time	Maximum Non-Coincident Power Demands for Month: House (KW)	Heat Pump (KW)	Hot Water Heater (KW)	Range (KW)	Misc. (KW)	Monthly Coincidence Factor for the House
			2-Bedroom Houses					
14	June 21, 1959	1430	13.9	5.6	4.8	5.0	10.1	.55
180	July 4, 1959	1230	14.7	3.2	5.4	3.5	6.8	.78
263	June 26, 1959	1100	13.4	3.1	5.1	1.0	6.0	.89*
301	July 1, 1959	1630	13.4	3.5	5.1	3.5	10.2	.57
585	June 10, 1959	1015	13.4	3.1	5.0	3.4	5.5	.79
843	June 22, 1959	1030	12.2	4.4	5.4	3.8	6.3	.61
			3-Bedroom Houses					
4	June 29, 1959	0830	11.8	4.4	5.3	5.4	6.2	.57
74	July 1, 1959	2000	13.4	3.3	4.7	4.0	7.2	.70
163	June 8, 1959	1145	15.1	7.7	5.2	4.4	11.4	.53
172	July 4, 1959	0845	14.4	3.2	4.8	4.3	6.9	.74
577	June 22, 1959	2030	12.5	3.2	5.1	5.4	7.6	.59
587	July 6, 1959	1130	14.1	3.2	5.0	2.9	6.9	.78
656	July 5, 1959	1715	13.0	7.8	5.0	3.9	7.6	.56
770	June 8, 1959	2100	14.2	3.1	4.8	2.4	8.1	.77
			4-Bedroom Houses					
467	June 28, 1959	1430	15.4	5.8	4.8	3.4	9.6	.65
468	June 27, 1959	1215	15.9	5.9	4.8	5.0	6.1	.73
Average for 16 Houses			13.8	4.4	5.0	3.8	7.7	.68

* Probably high due to faulty range watthour meter

Table 30

NON-COINCIDENT TOTAL AND COMPONENT 15-MINUTE MAXIMUM POWER DEMANDS
OCCURRING AT ANYTIME DURING THE MONTH IN EACH SAMPLE HOUSE
July 7 to August 7, 1959

Contractors House No.	Time of Maximum Total Demand for House		Maximum Non-Coincident Power Demands for Month					Monthly Coincidence Factor for the House
	Date	Time	House (KW)	Heat Pump (KW)	Hot Water Heater (KW)	Range (KW)	Misc. (KW)	
			2-Bedroom Houses					
14	July 20, 1959	1145	12.7	3.2	4.9	4.4	8.8	.60
180	Aug. 5, 1959	0900	11.7	3.1	0*	2.0	9.8	.79
263	Aug. 3, 1959	1230	14.0	3.1	4.9	1.0	6.4	.91*
301	July 20, 1959	0845	13.8	3.5	5.1	4.1	6.1	.73
585	Aug. 6, 1959	1800	14.9	3.4	4.8	3.2	6.2	.85
843	July 17, 1959	1830	11.7	3.3	5.2	4.8	7.5	.56
			3-Bedroom Houses					
4	July 10, 1959	1600	13.7	5.0	5.1	3.1	10.5	.58
74	Aug. 1, 1959	1145	13.2	5.5	4.7	4.9	5.9	.63
163	July 11, 1959	1445	17.7	3.3	5.0	5.3	9.8	.76
172	Aug. 5, 1959	1145	14.4	3.2	4.6	3.0	5.8	.87
577	July 25, 1959	1500	14.0	3.4	4.8	6.9	6.5	.65
587	July 8, 1959	1900	13.2	3.3	4.9	2.7	6.2	.77
656	July 9, 1959	1145	13.6	3.5	4.7	2.5	8.6	.70
770	Aug. 6, 1959	1330	12.6	6.4	4.8	3.5	7.1	.58
			4-Bedroom Houses					
467	July 16, 1959	1130	13.6	5.5	4.6	3.0	6.6	.69
468	Aug. 6, 1959	1630	16.8	6.0	4.7	4.3	5.5	.82
Average for 16 Houses			13.9	4.0	4.6	3.7	7.3	.72

* Probably high due to faulty range watthour meter

Table 31

NON-COINCIDENT TOTAL AND COMPONENT 15-MINUTE MAXIMUM POWER DEMANDS OCCURRING AT ANYTIME DURING THE MONTH IN EACH SAMPLE HOUSE
August 7 to September 8, 1959

Contractors House No.	Time of Maximum Total Demand for House		Maximum Non-Coincident Power Demands for Month					Monthly Coincidence Factor for the House
	Date	Time	House (KW)	Heat Pump (KW)	Hot Water Heater (KW)	Range (KW)	Misc. (KW)	
			2-Bedroom Houses					
14	Aug. 20, 1959	1215	12.8	3.1	4.9	4.0	6.1	.71
180	Sep. 2, 1959	1315	13.4	3.1	5.1	3.9	4.6	.80
263	Sep. 7, 1959	1200	13.5	3.1	4.9	0.5	5.8	.94*
301	Aug. 16, 1959	1030	14.0	3.5	5.1	3.8	6.3	.74
585	Aug. 25, 1959	1745	13.7	5.4	4.9	5.1	5.1	.67
843	Aug. 28, 1959	1245	11.5	1.6	5.2	4.1	7.7	.62
			3-Bedroom Houses					
4	Sep. 8, 1959	0930	15.6	5.0	5.0	3.9	8.4	.70
74	Aug. 23, 1959	1400	15.3	4.9	4.6	4.2	7.5	.72
163	Sep. 4, 1959	1615	15.6	5.1	5.0	4.5	6.1	.75
172	Aug. 17, 1959	0645	12.8	3.2	4.6	3.3	5.6	.77
577	Aug. 20, 1959	0815	13.6	3.2	4.8	6.1	5.8	.68
587	Aug. 10, 1959	1130	12.4	5.6	4.9	1.9	5.1	.71
656	Sep. 1, 1959	0945	13.4	3.4	4.7	4.0	6.2	.73
770	Aug. 17, 1959	0645	13.2	3.1	4.5	3.8	7.1	.71
			4-Bedroom Houses					
467	Aug. 21, 1959	1415	15.2	5.8	4.6	4.3	5.4	.76
468	Aug. 29, 1959	1415	16.8	7.2	4.6	4.6	5.5	.77
Average for 16 Houses			13.9	4.1	4.8	4.0	6.1	.73

* Probably high due to faulty watthour meter

The coincidence factor for individual houses ranged from 0.54 to 0.87 during the 3 winter months, but the average value for all houses in the sample varied between 0.68 and 0.73 in the 3-month period.

Tables 29 to 31, for the 3 summer months used for analysis, show that the maximum power demands for the various components were fairly consistent from month to month based on the averages for all the sample houses. The average of the maximum values for the total house load in all houses was 3 to 4 KW lower for the summer months than for the winter months, due almost entirely to a corresponding decrease in the maximum power demands for the heat pump in the summer. The maximum power demands of the water heater, electric range, and miscellaneous devices were comparable winter and summer.

The coincidence factor for individual houses ranged from 0.53 to 0.94 during the 3 summer months, but the average value for all houses in the sample varied between 0.60 and 0.73 in the 3-month period, exactly the same range as for the average winter values. It will be noted in Tables 29 to 30 that the coincidence factor for house 263 is significantly higher than those for all other houses. It is believed that this may have been caused by a faulty watthour meter registration on the electric range since the maximum power demands for this component were unusually low.

3.5(d) Frequency Distribution of Power Demand Values

It was noted in Figures 3 to 12 that high 15-minute power demand values, somewhat lower than the monthly maximum value, occurred at various times throughout the day, usually during the period from 0630 to 2000 hours. The exact number of these occurrences cannot be counted in Figures 3 to 12 because these graphs show only the one highest value of power demand occurring at each 15-minute interval of the day. Information on the frequency of these high power demands is of importance in determining the requirements of the distribution system and in selecting possible devices for limiting the magnitude of the maximum power demand in the houses.

Figures 19 to 28 were plotted to show the frequency of recurrence of 15-minute power demands at various levels of demand. The curves are plotted for the same five houses for which the daily pattern of power demand was illustrated in Figures 3 to 12. Because the higher values were of primary interest, only demands greater than 5 KW were used. Data for both August 1959 and January 1960 are shown.

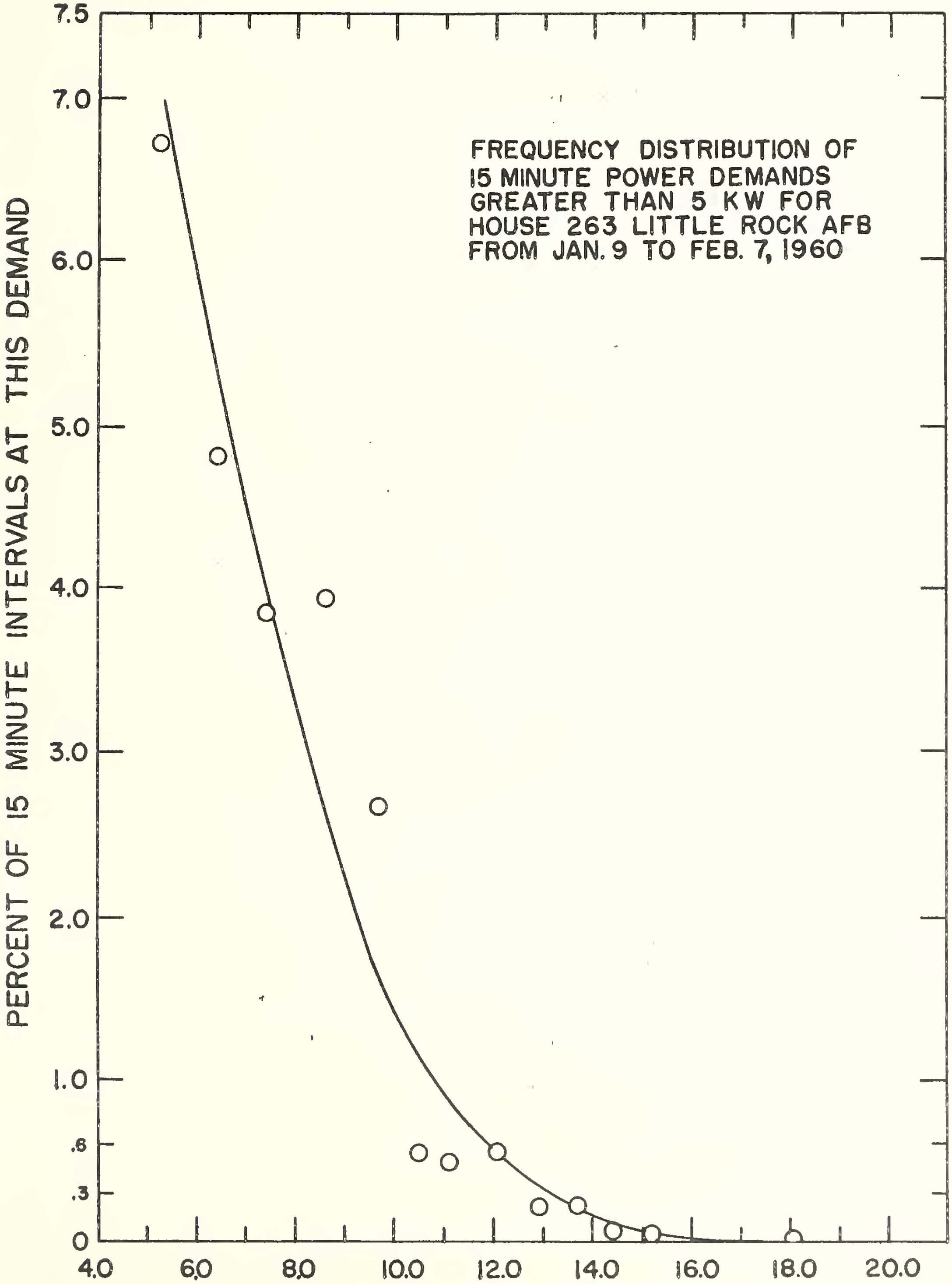


FIG. 19 15-MINUTE POWER DEMAND, K W

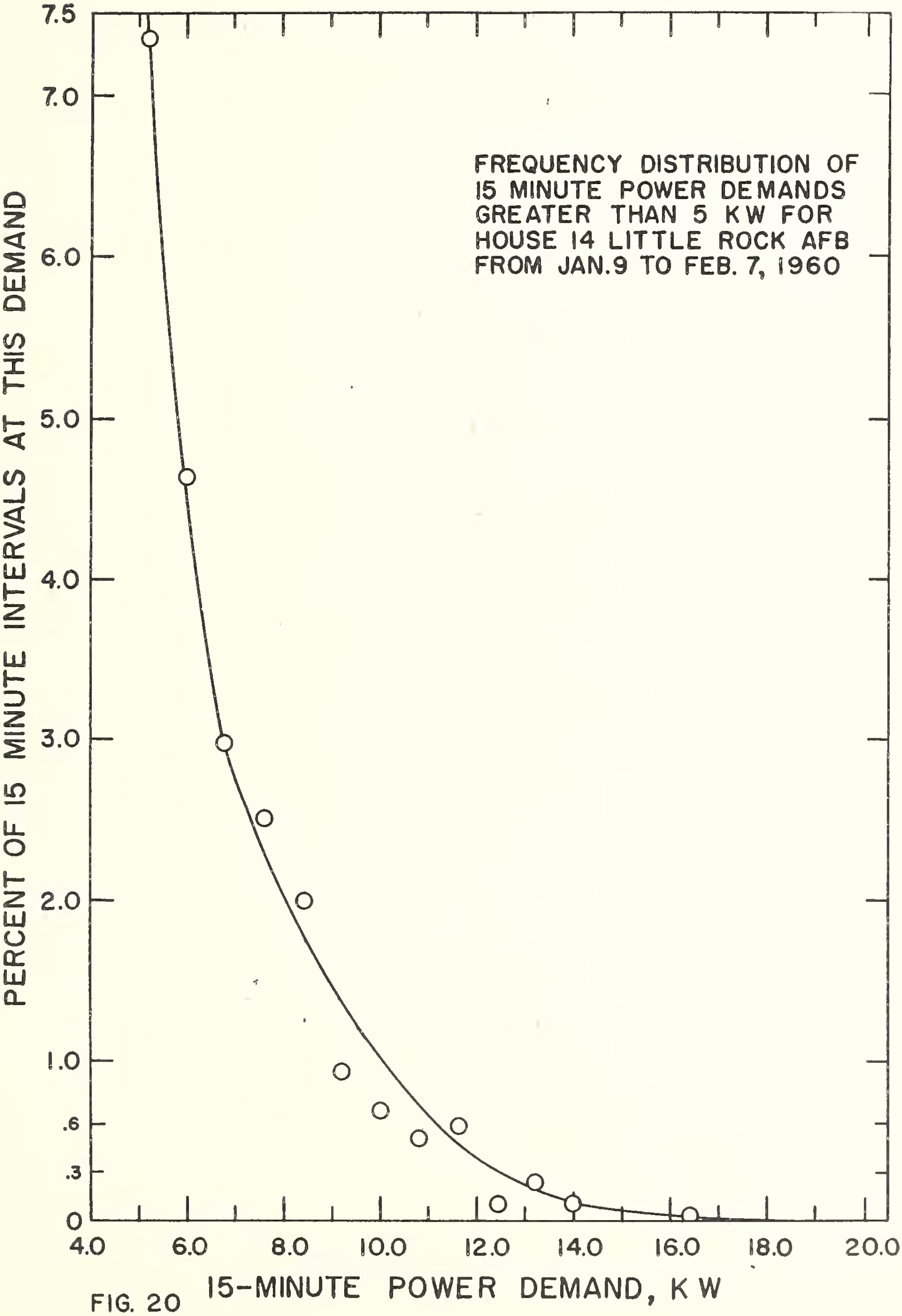

FREQUENCY DISTRIBUTION OF
15 MINUTE POWER DEMANDS
GREATER THAN 5 KW FOR
HOUSE 14 LITTLE ROCK AFB
FROM JAN.9 TO FEB. 7, 1960
PERCENT OF 15 MINUTE INTERVALS AT THIS DEMAND
7.5
7.0
6.0
5.0
4.0
3.0
2.0
1.0
.6
.3
0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
15-MINUTE POWER DEMAND, KW

FIG. 20

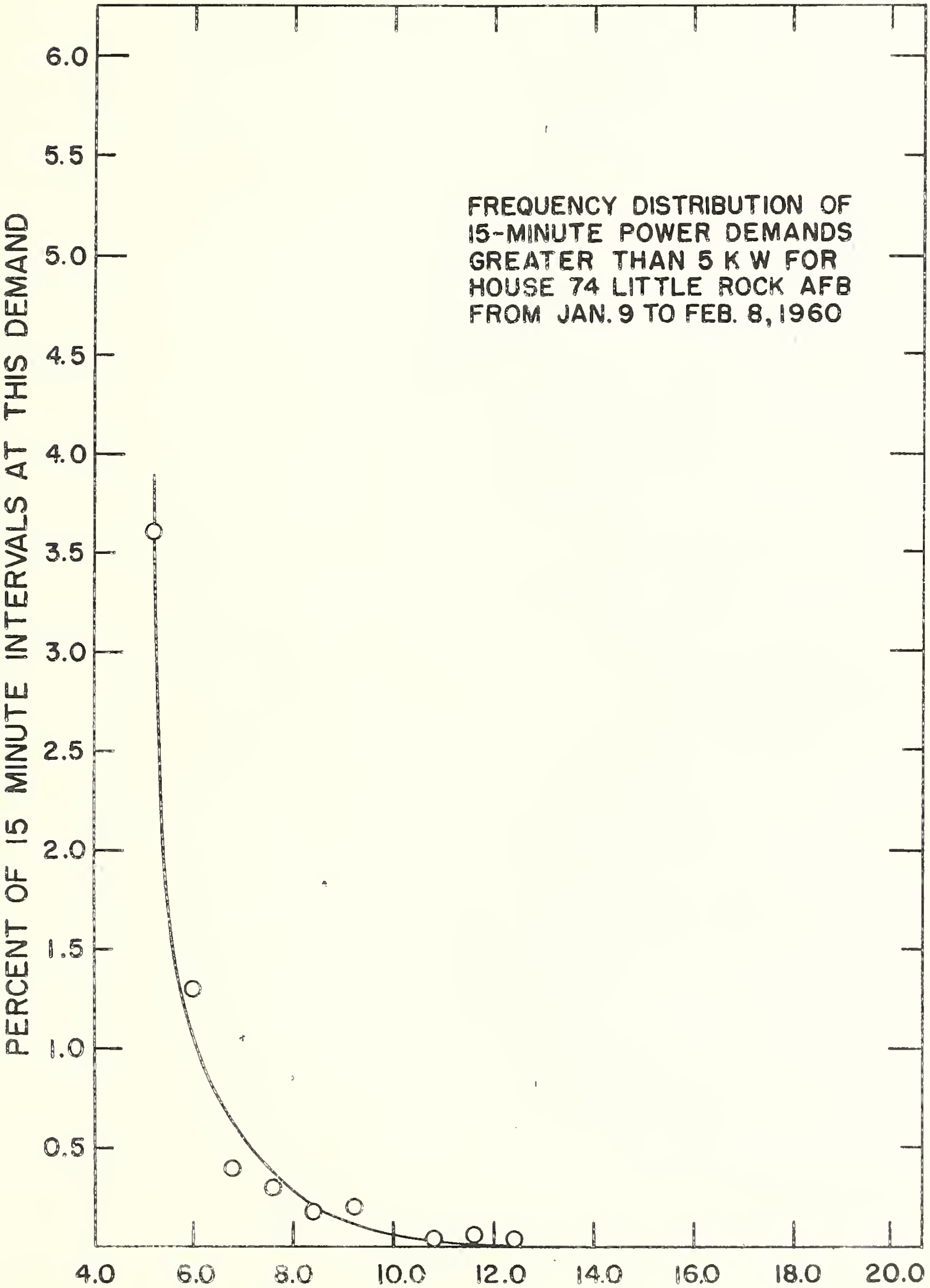
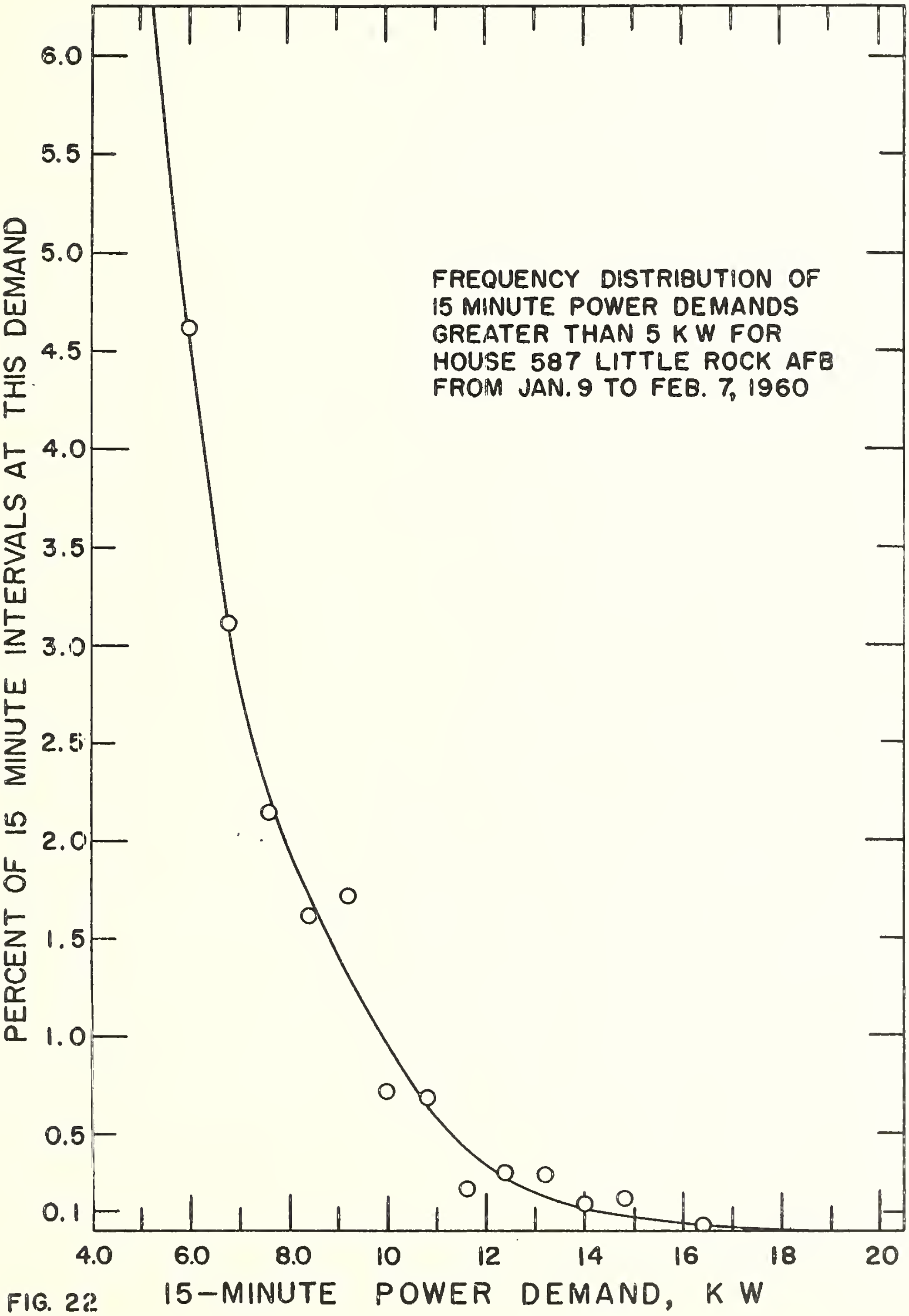


FIG. 21 15—MINUTE POWER DEMAND, KW



FREQUENCY DISTRIBUTION OF
15 MINUTE POWER DEMANDS
GREATER THAN 5 KW FOR
HOUSE 587 LITTLE ROCK AFB
FROM JAN. 9 TO FEB. 7, 1960
PERCENT OF 15 MINUTE INTERVALS AT THIS DEMAND
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.1
4.0
6.0
8.0
10
12
14
16
18
20
15-MINUTE POWER DEMAND, KW

FIG. 22

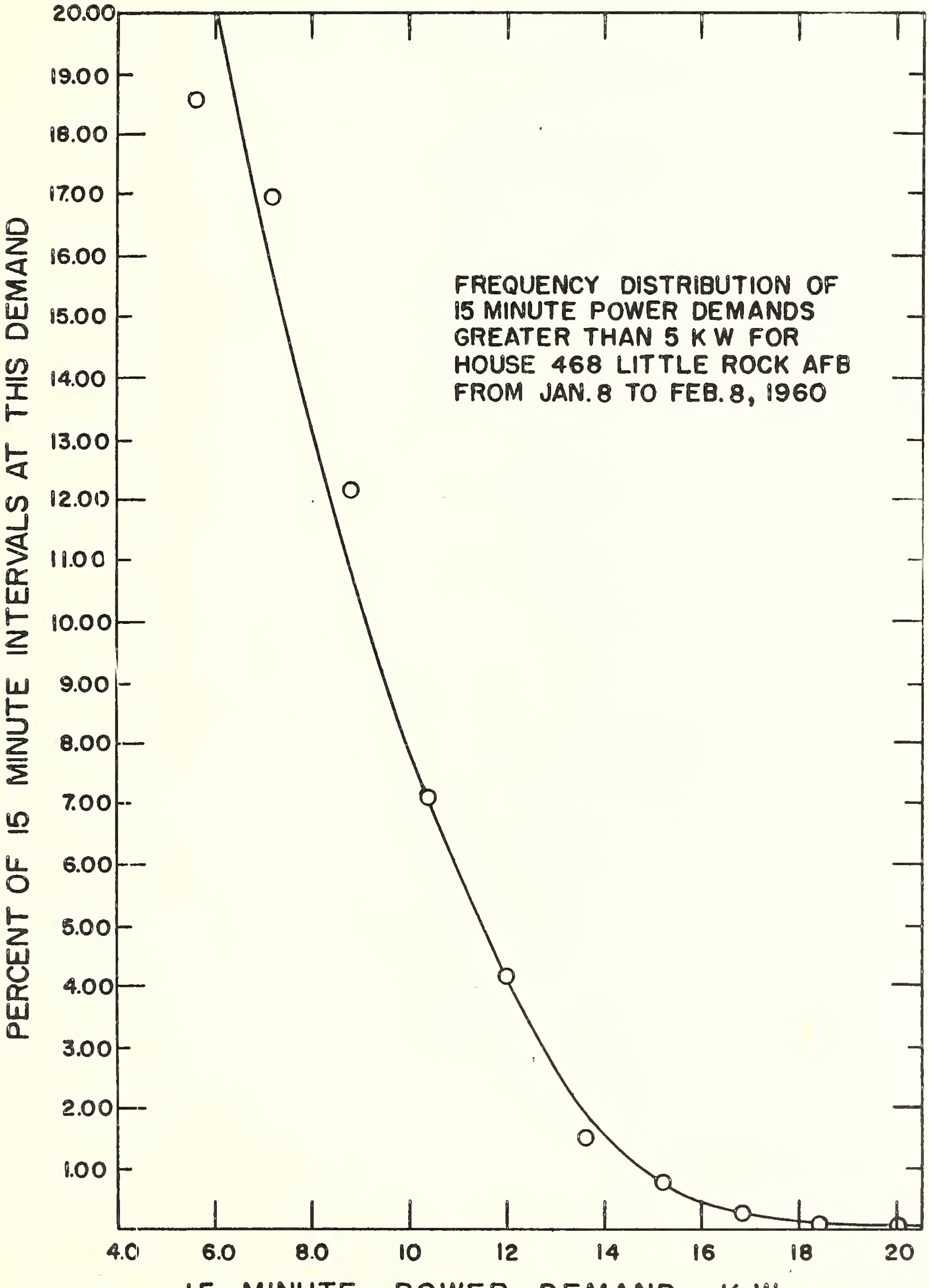
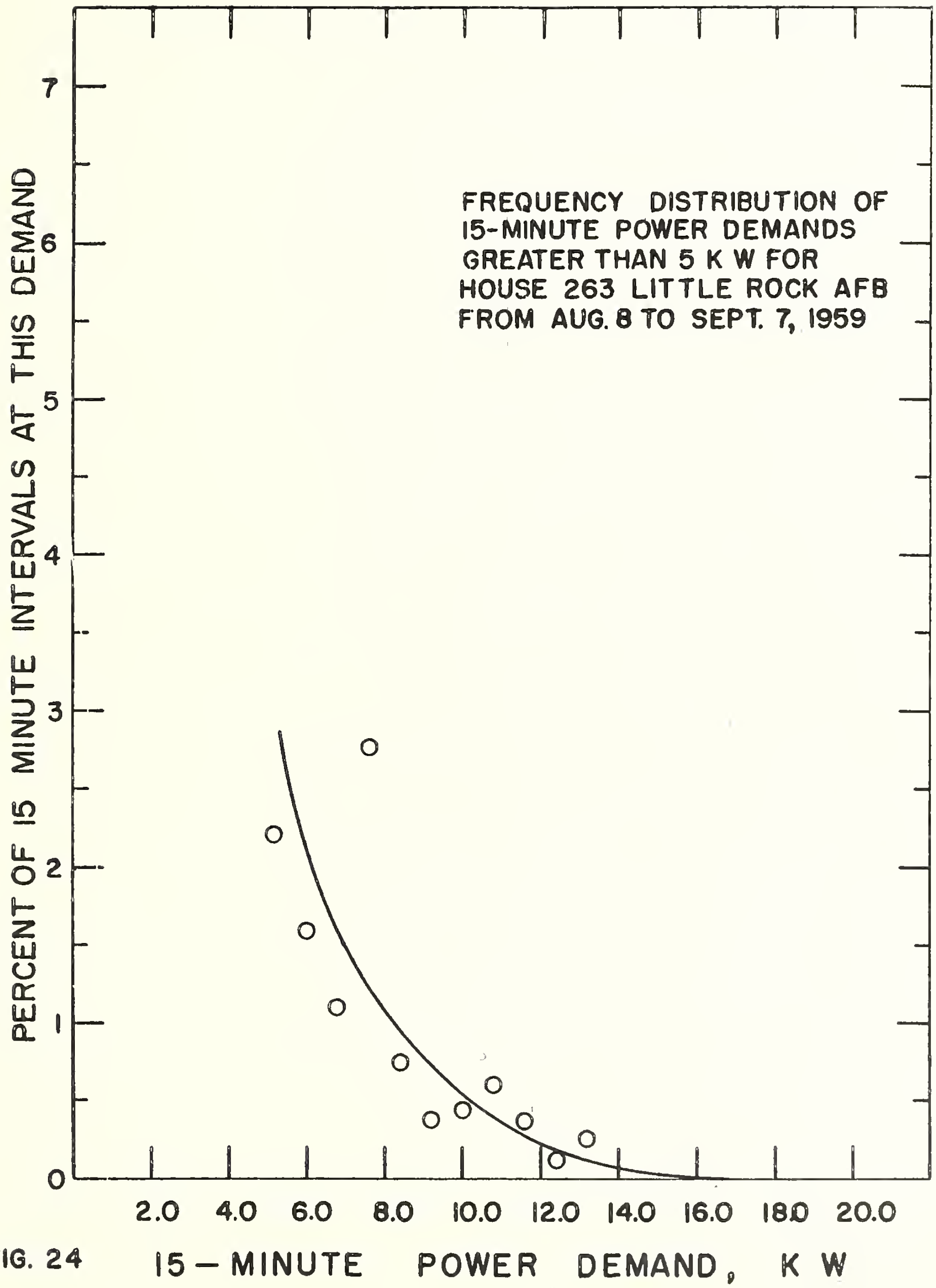


FIG. 23 15-MINUTE POWER DEMAND, KW



FREQUENCY DISTRIBUTION OF
15-MINUTE POWER DEMANDS
GREATER THAN 5 K W FOR
HOUSE 263 LITTLE ROCK AFB
FROM AUG. 8 TO SEPT. 7, 1959
PERCENT OF 15 MINUTE INTERVALS AT THIS DEMAND
0
1
2
3
4
5
6
7
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
15 — MINUTE POWER DEMAND, K W

FIG. 24

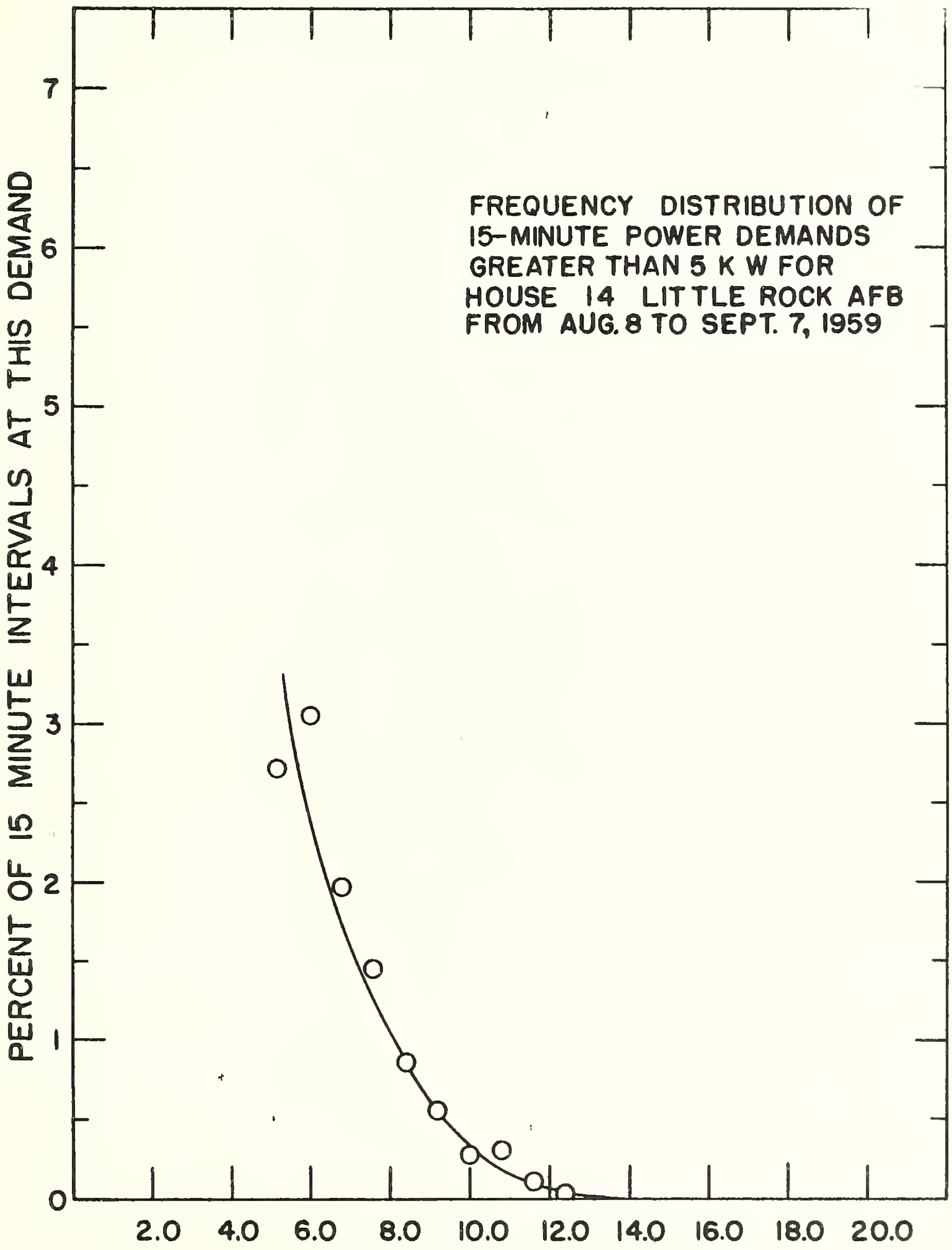


FIG. 25 15 — MINUTE POWER DEMAND, K W

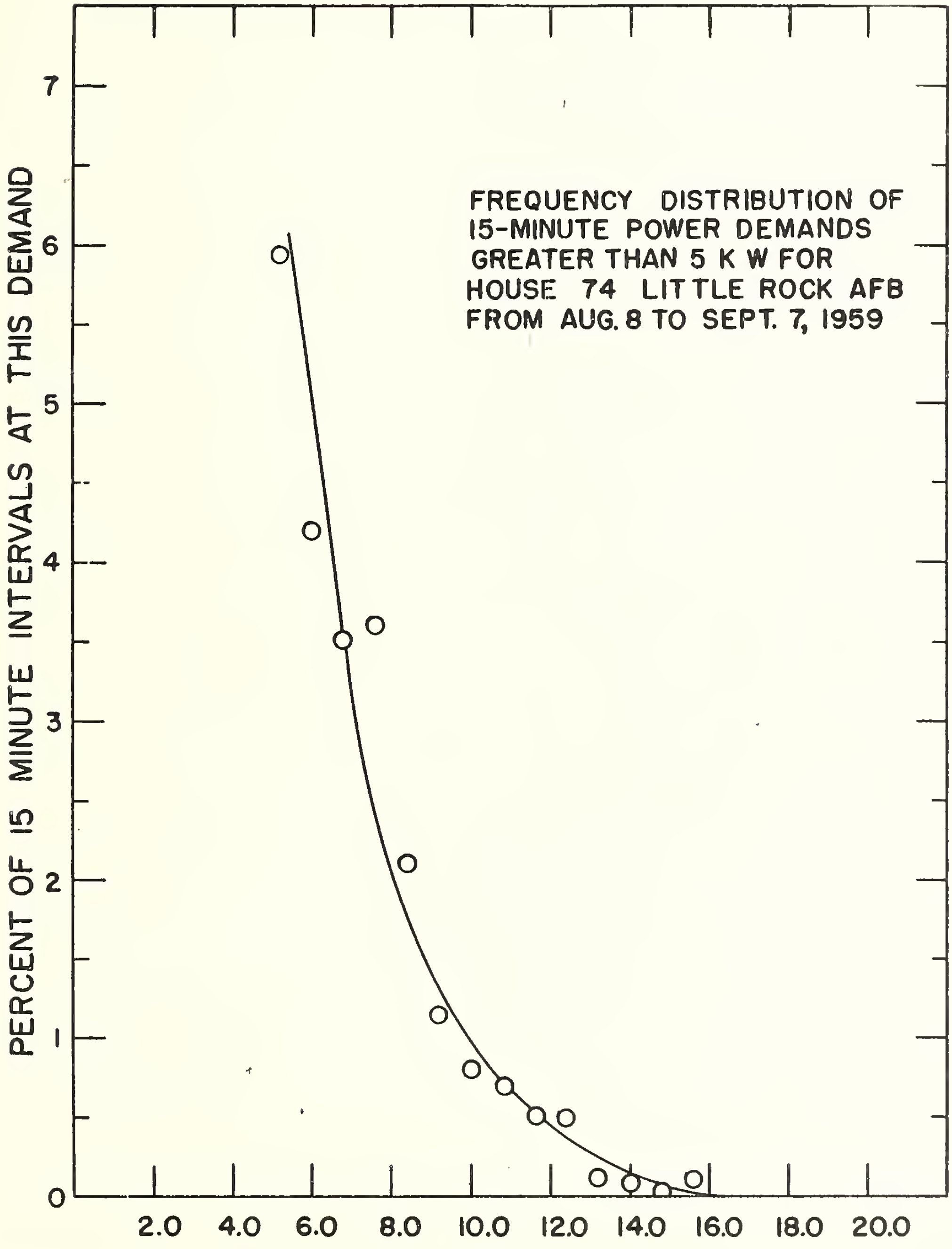


FIG. 26 15 — MINUTE POWER DEMAND, K W

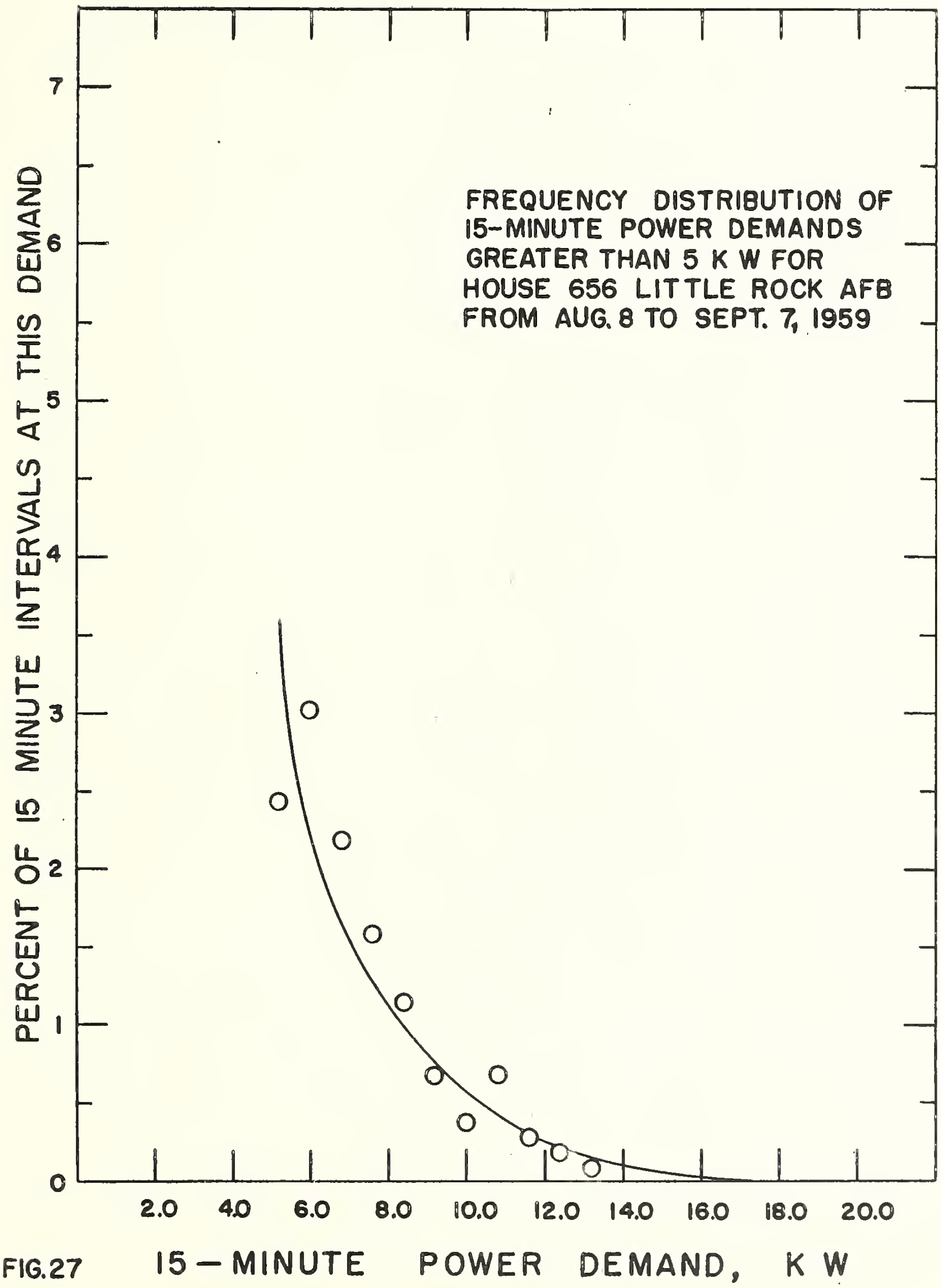

FREQUENCY DISTRIBUTION OF
15-MINUTE POWER DEMANDS
GREATER THAN 5 K W FOR
HOUSE 656 LITTLE ROCK AFB
FROM AUG. 8 TO SEPT. 7, 1959
PERCENT OF 15 MINUTE INTERVALS AT THIS DEMAND
0
1
2
3
4
5
6
7
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
15 — MINUTE POWER DEMAND, K W

FIG. 27

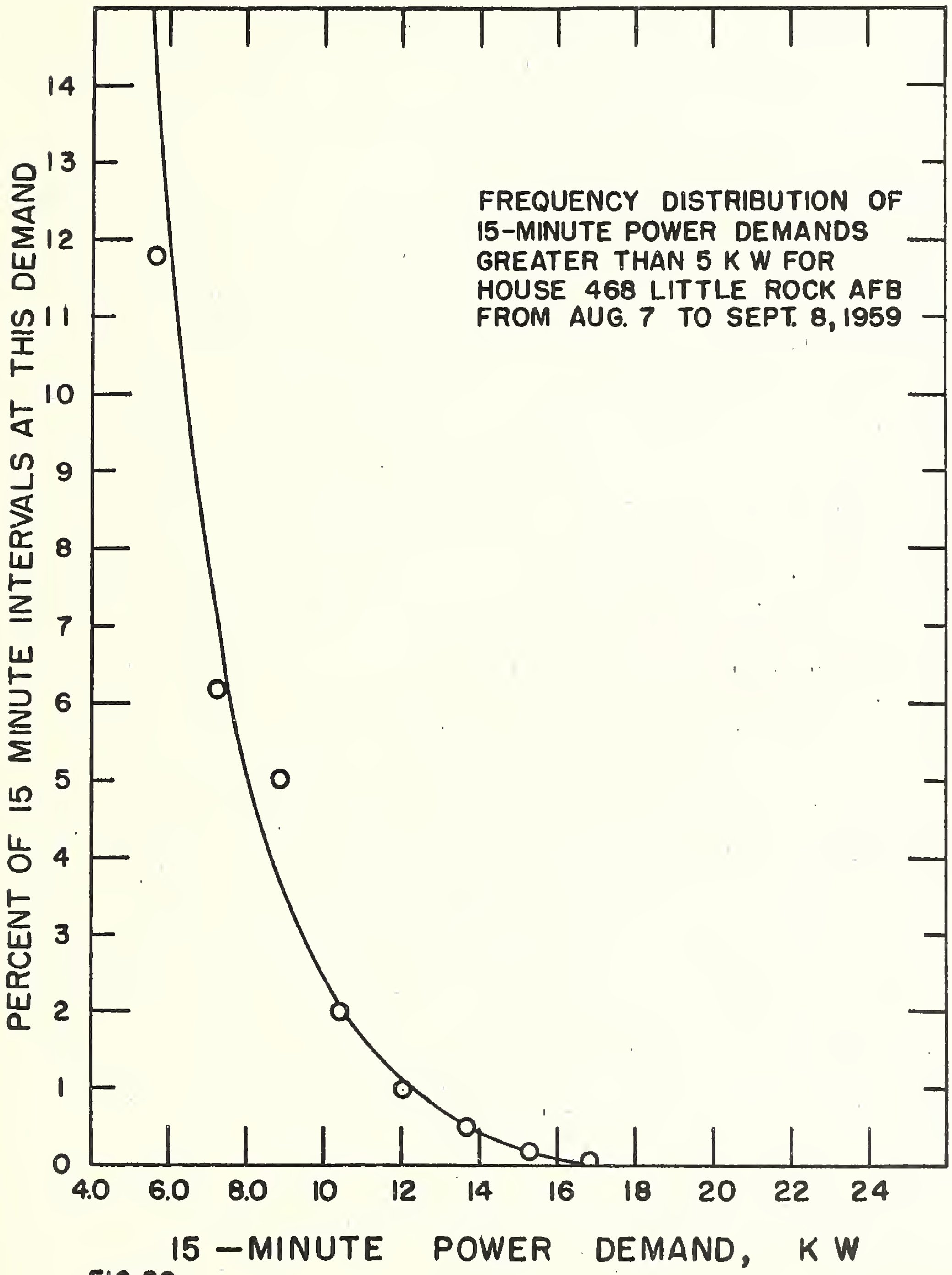

FREQUENCY DISTRIBUTION OF
15-MINUTE POWER DEMANDS
GREATER THAN 5 K W FOR
HOUSE 468 LITTLE ROCK AFB
FROM AUG. 7 TO SEPT. 8, 1959
PERCENT OF 15 MINUTE INTERVALS AT THIS DEMAND
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
4.0
6.0
8.0
10
12
14
16
18
20
22
24
15 —MINUTE POWER DEMAND, K W

FIG. 28

An inspection of Figures 19 to 28 shows that the frequency distribution curves were exponential in shape for the range of power demand values of 5 KW and higher. Mathematical expressions were derived for some of the curves indicating that they were generally of the form $y = Ce^{-kx}$ in which the values of constants C and k differed somewhat for different houses, x represented the 15-minute power demand in KW, and y represented the percent of the total monthly demand intervals at this value of power demand.

The number of 15-minute intervals in the month for which the power demand would be expected to be at any selected value from 5 KW to the maximum can be read directly from Figures 19 to 28 for this group of sample houses. Tables 32 and 33 show the power demands corresponding to frequencies of 0.1, 1.0 and 5.0 percent for the period January 8, 1960 to February 8, 1960, and to frequencies of 0.1, 1.0, and 3.0 percent for the period August 8, 1959 to September 7, 1959 taken from Figures 19 to 28. Since there are ninety-six 15-minute periods in a day, a frequency of 1 percent corresponds to about one 15-minute period per day on the average. These tables show that the demands of houses 14, 263, and 587 were similar during January and that those for houses 14, 263, and 656 were similar during August. The demands for house 468, a 4-bedroom house, were larger than the others for both months whereas the demands for house 74 were the lowest of the group during January and second highest in August.

Using the data for house 14, curves were plotted from the data for January and for August for the frequency of recurrence of all demands from 0 to maximum power demand. Both curves are of the exponential form $y = Ce^{-kx}$, either in part or totally, as illustrated in Figures 29 and 30 showing the curves. The curve drawn through the observed data for January in Figure 29 fits the exponential curve reasonably well from 6 KW to the maximum of about 18 KW, but bends to the right from the exponential curve for demand values from 3.5 to 6 KW.

The reasons for the significant difference in the shape of the frequency curve below demand levels of 3.5 KW between January and August are not fully understood. However, Figure 8 indicates that the heat pump probably was not in operation during the night in house 14 thus reducing the occurrence of power demands on the order of 3.5 KW considerably during the night, and increasing the frequency of smaller demands. It is also probable that the total number of hours in January

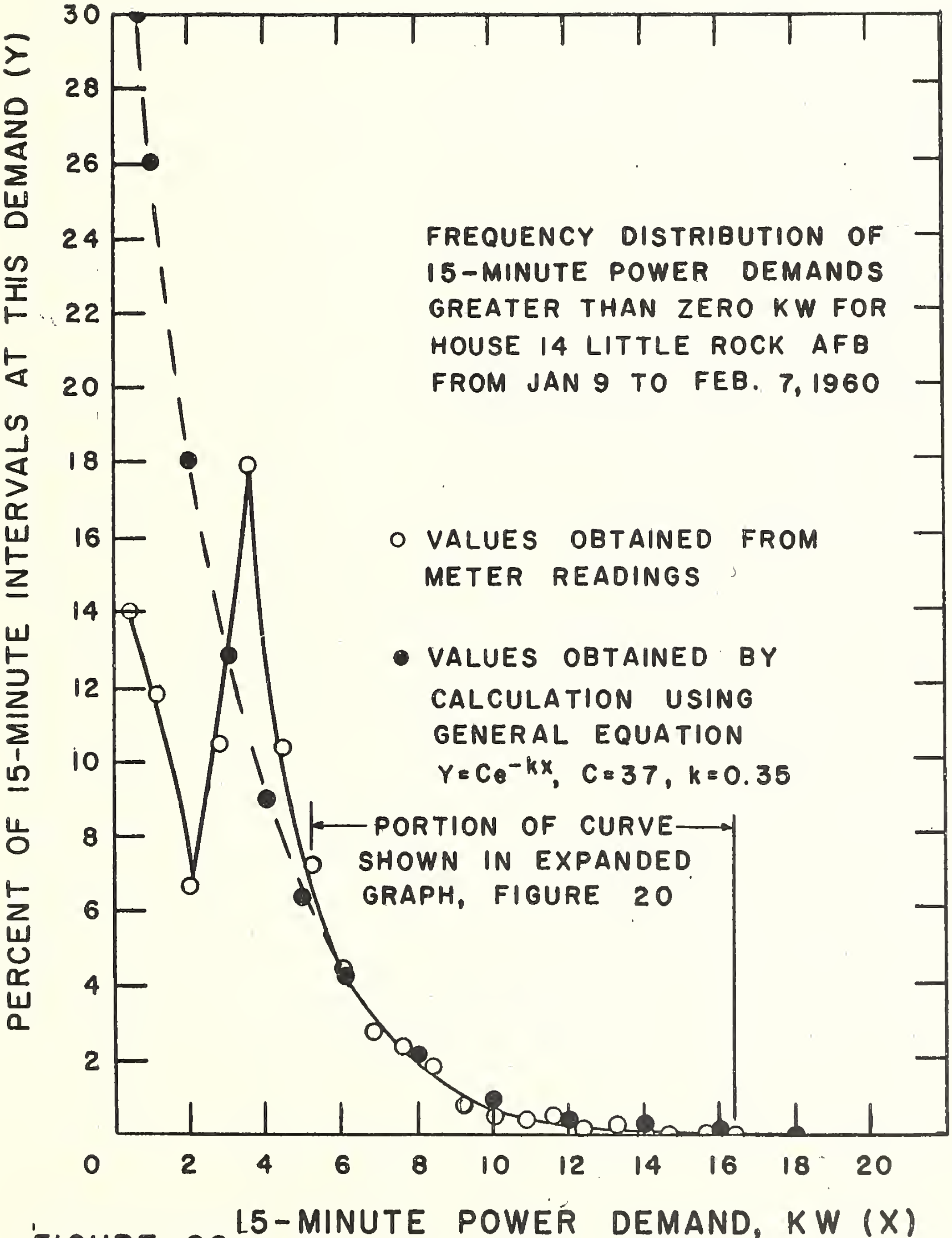

PERCENT OF 15-MINUTE INTERVALS AT THIS DEMAND (Y)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
FREQUENCY DISTRIBUTION OF 15-MINUTE POWER DEMANDS GREATER THAN ZERO KW FOR HOUSE 14 LITTLE ROCK AFB FROM JAN 9 TO FEB. 7, 1960
○ VALUES OBTAINED FROM METER READINGS
● VALUES OBTAINED BY CALCULATION USING GENERAL EQUATION $Y=Ce^{-kx}$, C=37, k=0.35
PORTION OF CURVE SHOWN IN EXPANDED GRAPH, FIGURE 20
15-MINUTE POWER DEMAND, KW (X)

FIGURE 29

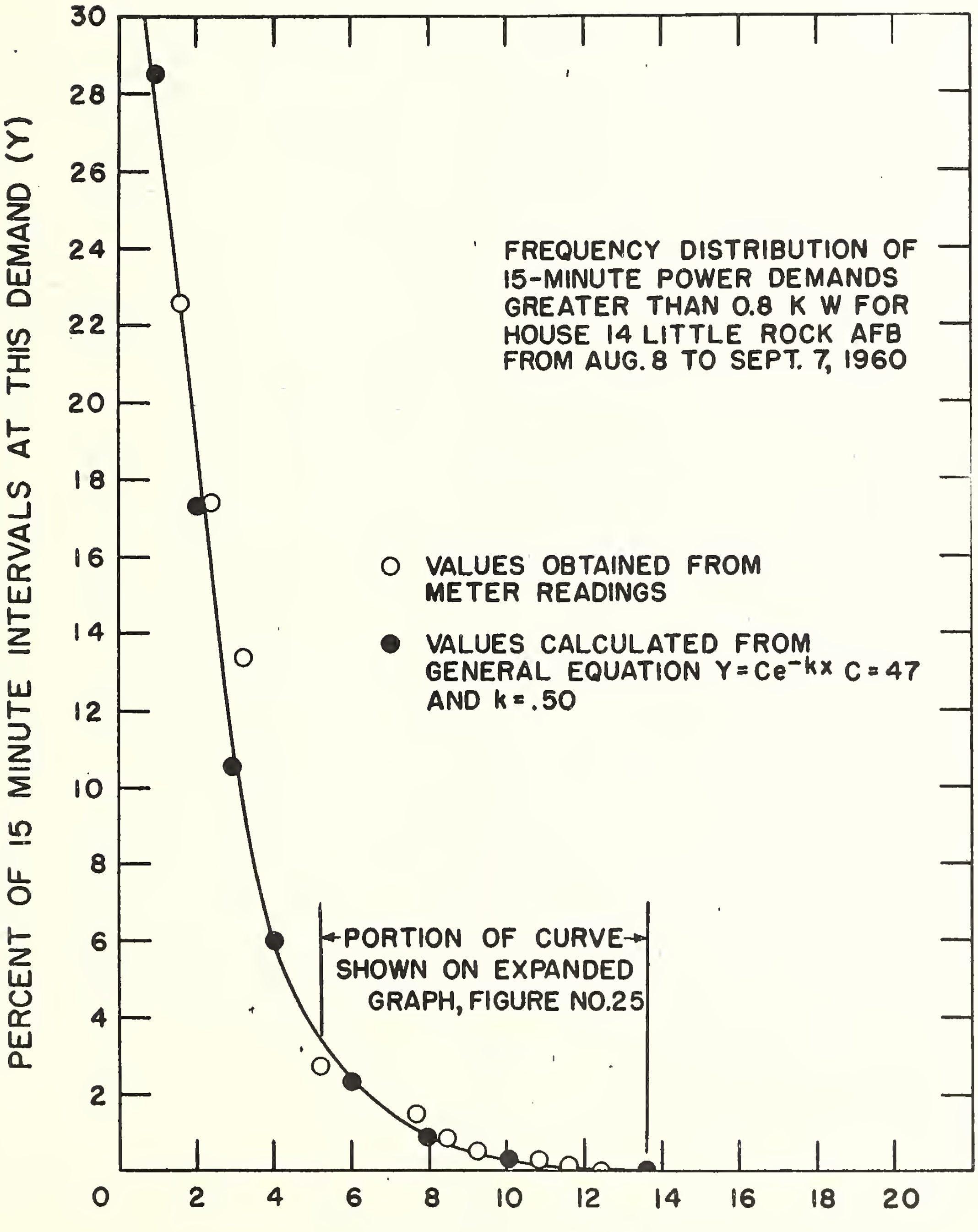

FREQUENCY DISTRIBUTION OF 15-MINUTE POWER DEMANDS GREATER THAN 0.8 K W FOR HOUSE 14 LITTLE ROCK AFB FROM AUG. 8 TO SEPT. 7, 1960
VALUES OBTAINED FROM METER READINGS
VALUES CALCULATED FROM GENERAL EQUATION Y=Ce^-kx C=47 AND k=.50
PORTION OF CURVE SHOWN ON EXPANDED GRAPH, FIGURE NO.25
PERCENT OF 15 MINUTE INTERVALS AT THIS DEMAND (Y)
15-MINUTE POWER DEMAND, KW (X)
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
2
4
6
8
10
12
14
16
18
20

FIGURE 30

Table 32

Power Demands at Selected Frequencies of Recurrence
Period January 8, 1960 to February 8, 1960

Selected Frequency of Recurrence, %	15-Minute Power Demand, KW House No. 14	74	263	468	587
0.1	14.2	9.4	14.8	18.0	14.8
1.0	10.0	6.1	10.8	15.0	9.9
5.0	5.8	<5.0	6.6	11.5	5.8

Table 33

Power Demands at Selected Frequencies of Recurrence
Period August 8, 1959 to September 7, 1959

Selected Frequency of Recurrence, %	15-Minute Power Demand, KW House No. 14	74	263	468	656
0.1	11.4	14.4	13.5	16.0	13.7
1.0	8.0	9.9	8.2	12.2	8.4
3.0	5.5	7.1	5.2	9.3	5.4

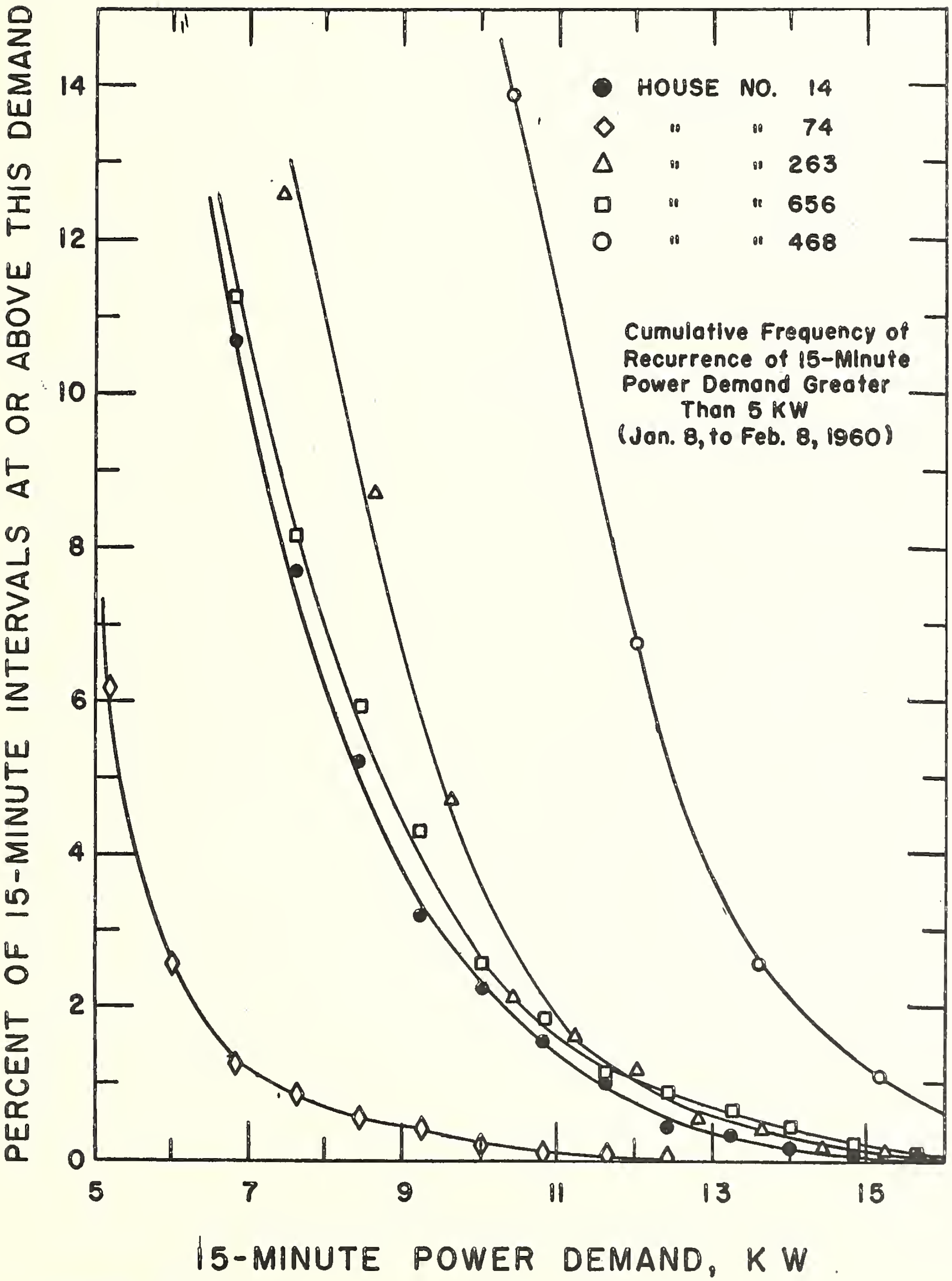
that required steady operation of the heat pump for heating exceeded the total number of hours in August that required steady operation of the heat pump for cooling. Table 34 shows the frequency of recurrence of outdoor temperatures in consecutive 5-degree temperature bands from 20°F to 75°F.

The frequencies of recurrence of 15-minute power demands at or above selected levels of demand from about 5 KW to the maximum are shown in Figures 31 and 32. The same data were used for these figures as for Figures 19 to 28, but in this case the frequencies shown as ordinates were plotted on a cumulative basis. The data for five houses are shown in Figure 31 for the month of January 1960 and the data for four of the same houses and one other house are shown in Figure 32 for the month of August 1959. These curves can be used to determine what part of a day or a month, on the average, will correspond to 15-minute power demands at any selected value or higher. For example, Figure 31 shows that the 15-minute power demand for house 468 will be 15.2 KW or higher, 1 percent of the time, or about one 15-minute period per day on the average. In Figure 32, it is shown that the 15-minute power demands that will be equaled or exceeded 1 percent of the time in August, range from 9.6 to 13.2 KW in the five sample houses. Curves of this type can be used to evaluate the probable amount of time that the energy use habits in a given house would be affected by a device which limited the 15-minute demand to any selected value.

Table 34

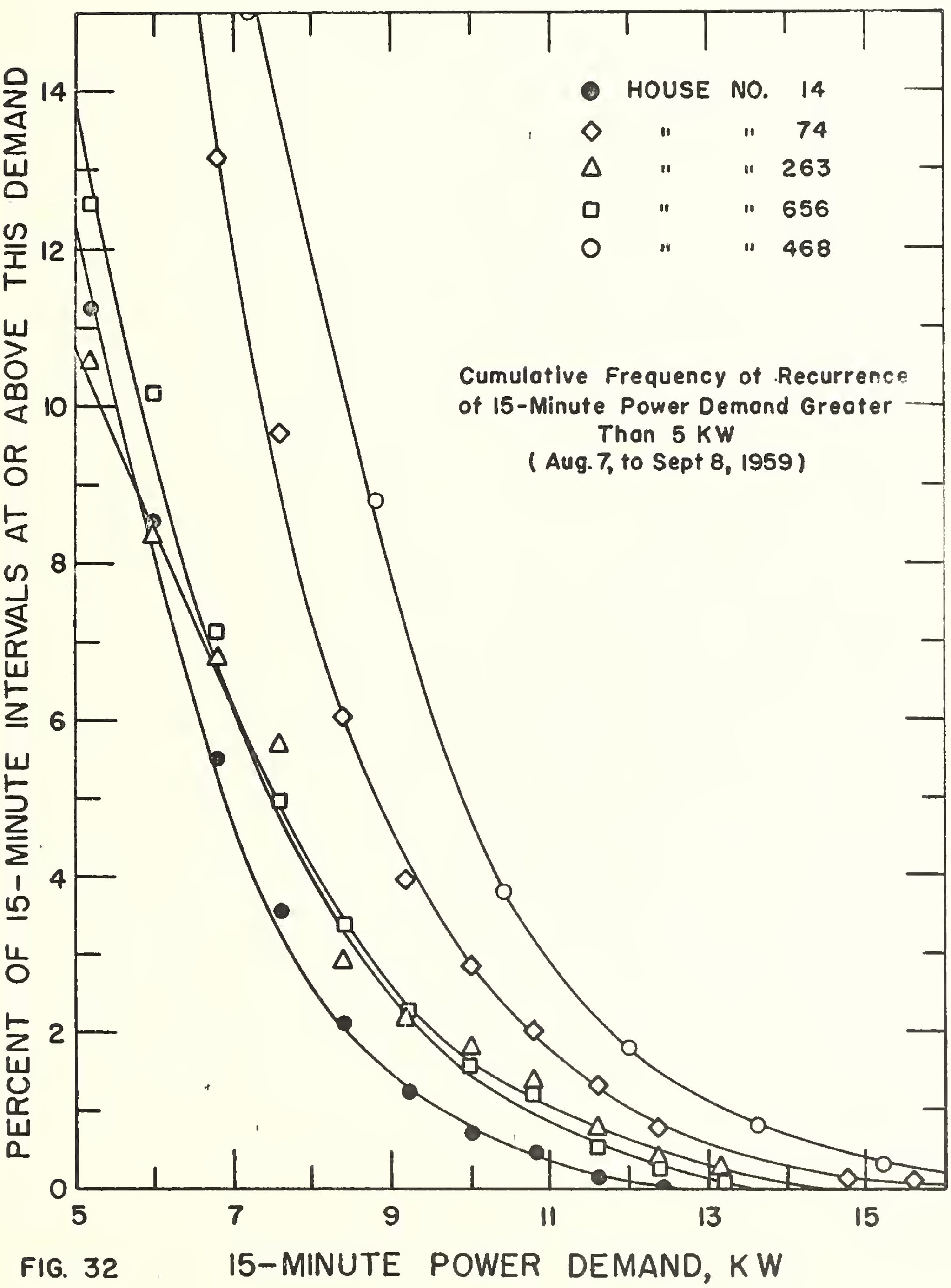
Frequency of Recurrence of Outdoor Temperatures in Selected Temperature Ranges at Little Rock Air Force Base January 8 to February 8, 1960

Temperature Range (°F)	No. of Hours with Temperatures in this Range
20 to 25	45
25 to 30	70
30 to 35	90
35 to 40	150
40 to 45	120
45 to 50	95
50 to 55	75
55 to 60	40
60 to 65	35
65 to 70	20
70 to 75	5



PERCENT OF 15-MINUTE INTERVALS AT OR ABOVE THIS DEMAND
0
2
4
6
8
10
12
14
5
7
9
11
13
15
15-MINUTE POWER DEMAND, K W
HOUSE NO. 14
" " 74
" " 263
" " 656
" " 468
Cumulative Frequency of
Recurrence of 15-Minute
Power Demand Greater
Than 5 KW
(Jan. 8, to Feb. 8, 1960)

FIGURE 31



HOUSE NO. 14
" " 74
" " 263
" " 656
" " 468
Cumulative Frequency of Recurrence of 15-Minute Power Demand Greater Than 5 KW (Aug. 7, to Sept 8, 1959)
PERCENT OF 15-MINUTE INTERVALS AT OR ABOVE THIS DEMAND
0
2
4
6
8
10
12
14
5
7
9
11
13
15
15-MINUTE POWER DEMAND, KW

FIG. 32

3.6 Relation of Maximum Demand for the Entire Air Base to that for the Housing Area Only

Table 35 shows the magnitudes of the monthly 15-minute maximum demands from April 1959 through February 1960, for both the housing area by itself and the entire air base. It also shows the times that the monthly maximum demands occurred for both the housing area and the entire air base. Comparison of the magnitude of the two maximum demands and the time of occurrence of these demands, shows clearly that the demand of the housing area was the predominant factor determining the monthly maximum demands for the entire air base. For these months, the maximum demand for the housing area ranged from 59 percent to 81 percent of that for the entire air base, with the higher percentages occurring in the winter months. For all months but five, the time of maximum demand for the housing area was coincident with that for the total base. In four of these five months, both maximum demands occurred on the same morning.

Table 35

Maximum 15-Minute Demands for Entire Air Base and Housing Area Only

	MAGNITUDE OF MONTHLY MAXIMUM DEMAND (KW)			TIME OF MONTHLY MAXIMUM DEMAND	
Time Period	Housing Area Only	Percent of Entire Air Base	Entire Air Base	Housing Area Only	Entire Air Base
Mar. 6 - Apr. 7, 1959	7,224	73	9,856	1100 3- 6-59	1100 3- 6-59
Apr. 7 - May 7, 1959	5,712	74	7,728	0700 4-13-59	0930 4- 9-59
May 7 - June 8, 1959	5,292	59	8,949	1230 5-29-59	1045 5-29-59
June 8 - July 7, 1959	7,560	71	10,600	1045 6-29-59	1030 6-29-59
July 7 - Aug. 7, 1959	7,308	65	11,200	1145 8- 3-59	1100 8- 3-59
Aug. 7 - Sep. 8, 1959	7,476	67	11,200	1100 8-24-59	1145 8-24-59
Sep. 8 - Oct. 8, 1959	6,384	64	9,968	1115 9-28-59	1115 9-28-59
Oct. 8 - Nov. 9, 1959	10,080	80	12,656	0915 11- 6-59	0915 11- 6-59
Nov. 9 - Dec. 10, 1959	11,508	80	14,448	0930 11-17-59	0930 11-17-59
Dec. 10, 1959 - Jan. 8, 1960	11,676	80	14,672	0915 1- 8-60	0915 1- 8-60
Jan. 8 - Feb. 8, 1960	12,432	80	15,568	1100 1-18-60	1100 1-18-60
Feb. 8 - Mar. 8, 1960	13,860	81	17,024	1015 3- 2-60	1015 3- 2-60

It should be noted that the lack of coincidence occurred during the summer months when the power usage for air conditioning was not as great as for winter operation. In agreement with much of the data given on the sample houses, the data in these tables show that in every instance, except one, the maximum demand for the housing area occurred during the morning hours.

4. METHODS OF LIMITING MAXIMUM POWER DEMAND IN THE HOUSING AREA

Various devices and methods have been used to limit the power demand in houses designed for electric heating and all-electric appliances. These usually take the form of some type of programming system and could either be administrative or mechanical-electrical. Certain intermittent operations in a house, such as laundering, could be staggered throughout the week by administrative order to provide diversity among a large group of houses. This type of programming has the advantage that no equipment is required to implement it, but it depends on voluntary cooperation in most cases and would cause inconvenience at times. The practicability of administrative programming can best be evaluated at the air base and will not be further considered in this discussion.

Mechanical-electrical devices for programming a group of component loads in a house might take any of the following forms:

(1) A non-preferential total load-limiting device,

(2) A total load-limiting device that gave preference to certain appliances,

(3) A load selector that permitted either of two appliances, but not both, to be energized at the same time,

(4) A relay which permitted one or more appliances to be energized, only if the load already energized was below some selected value,

(5) An off-peak water heating control on a time clock,

(6) A relay that cut the applied voltage from 230 volts to 115 volts on resistance elements such as the water heater and the supplementary resistance heaters in the heat pumps whenever the power demand reached some selected value,

(7) A control that cut off the water heater for intervals of 2 hours, more or less, during the time of the day when other loads were high, but with these 2-hour periods staggered throughout the period from about 0800 to 2000 hours.

In considering the type of programmer that would provide the best combination of reduction of maximum demand and minimum of inconvenience to the house occupants, the principal conclusions indicated by the foregoing analysis of the energy usage and power demand in the sample houses and the priority of the several load components in the house from a convenience standpoint should be taken into account.

The more significant conclusions indicated by the analysis of the data from the sample houses and from the entire housing area may be summarized as follows:

(a) The data in Tables 13 to 18 indicate that the maximum demand for the entire housing area was caused by a moderately high average demand in many houses rather than a coincidence of the maximum or very high demand in a minority of the houses. None of the 16 sample houses exhibited a monthly maximum demand coincident with the monthly maximum demand for the entire housing area, yet the average demand in the sample houses at the time of the monthly maximum for the entire housing area was about equal to the average for all of the houses at that time. This suggests that a program device which simply reduced the individual house maximum demand by 4 or 5 KW probably would not have a significant effect on the maximum demand for the entire housing area.

(b) Figures 3 to 12 show that the average power demand during the hours from about 0630 to 2000 was significantly higher than during the night hours. This difference was more significant in the summer than in the winter. Table 13 shows that, for four of the five sample houses studied, the rate of energy use during the hours from 0700 to 2300 was about 1 1/2 times

that used during the night hours from 2300 to 0700 in the month of January and that this ratio was about 4 to 1 between the same periods in the month of August. The difference was not as great as this in the fifth house, i.e. house 263 during August and house 468 during January. Figures 3 to 12 and Table 13 indicate that a program device that would shift some of the load from the daytime hours to the night hours would probably provide a lower maximum demand for the housing area.

(c) Tables 19 to 24 show that maximum power demand for the individual house averaged about 14 KW in the summer and about 17.5 KW in the winter with the heat pump, water heater, and miscellaneous devices being the principal contributors to these maximum demands. Tables 25 to 30 show that the coincidence factor between the maximum demands of the load components in each house and the maximum demand for the entire house load averaged about 0.71 both winter and summer.

(d) Figures 19 to 28 show that an exponential curve of the form $y = Ce^{-kx}$ represents fairly well the frequency of recurrence, y, of power demands from about 5 KW upward, and the numerical value of the 15-minute power demand, x. Cumulative curves, Figures 31 and 32, for frequency of recurrence of high power demands, show that power demands of 11.5 KW or more occur only about 1 percent of the time, or about 15 minutes per day, on the average, during a typical summer or winter month, except in the large 4-bedroom houses with two heat pumps. These cumulative frequency curves also indicate that power demands in excess of 7 KW occur for about 3 hours per day, on the average, except in the large 4-bedroom houses.

(e) Tables 5 to 9 show that the energy usage for heating was best correlated with the heating load on the basis of total energy used for heating, including the contribution made by the appliances other than the heat pump, the degree-days determined from average indoor temperature and mean daily outdoor temperature, and the floor area of the house. The average energy usage factor for the 16 sample houses based on a 5-month period from October 1959 through February 1960 was 2.18 KWH/degree-day (1,000 sq ft of floor area).

(f) Tables 10 to 12 show that the energy usage for cooling was best correlated with the cooling load on the basis of the energy used for the heat pump, the degree-days determined from the hourly values of outdoor temperature related to a 65°F base, and the floor area of the house. The average energy usage factor for the 16 sample houses based on a 3-month period from June through August 1959 was 2.1 KWH/degree-day (1,000 sq ft of floor area).

(g) The average annual energy used by the 16 sample houses (the sample consisted of 15 houses for a few months) for the 12-month period from March 1959 to February 1960 was 25,300 KWH. Of this total 48.6 percent was used by the heat pump, including the supplementary resistance heaters, for heating and cooling; 24.3 percent was used for water heating; 23.3 percent was used for miscellaneous devices, including a resistance heater in the bathroom; and 3.8 percent was used by the electric range. Annual costs can be derived from these data by applying appropriate rate schedules.

From a convenience standpoint it is believed that the various functions occurring in a house that require electric energy should be placed in the following order of decreasing priority:

(1) cooking
(2) heating and cooling
(3) miscellaneous uses, laundering, ironing, etc.
(4) water heating.

Cooking was given priority over heating partly because it can effectively substitute for heating for limited periods of time. Heating and cooling were given priority over miscellaneous uses because they are continuous requirements over rather long periods of time whereas the occupant has considerable choice in performing the miscellaneous functions of laundering, ironing, etc. Water heating was given the lowest priority because it is both possible and conventional to provide some storage of hot water whereas only very limited storage of heating and cooling effect is practical and the other functions cannot be stored.

The foregoing analysis and conclusions, regarding the average pattern of daily power demand, the coincidence factor within individual houses and among groups of houses, the probable cause of the maximum demand for the entire housing area, the frequency of recurrence of high demands, and the convenience considerations associated with the various energy-using activities in a house indicate that some type of programmer that caused the water heater to be energized only during periods of low or moderate demand by other appliances offers the best possibility of decreasing the maximum 15-minute power demands for the entire housing area. Program devices 3 through 7, listed at the beginning of Section 4 of this report, are different variations of this type of device.

Of all the devices listed it is believed that a relay which permitted one or more appliances to be energized, only if the load already energized was below some selected value, identified as (4) in the earlier listing, offers the best possibility of distributing the total daily energy use evenly over the 24-hour period. This type of relay would consist of a current coil in the lines serving the house that would interrupt the circuit to the water heater or possibly to the water heater and dryer, whenever the current reached some selected value. In this arrangement the electric service to the water heater, or water heater and dryer, would be connected on the line side of the current relay. This device would not limit the power demand or time of use of any component of the load except the one or two interrupted by the current relay, and would not prevent these from being energized except at times of high demand. The data on frequency of recurrence of high demands indicates that such a relay should be activated at a load somewhat above that caused by the compression system of the heat pump, but somewhat below the load when the compression system and supplementary resistance heaters were both energized. That is, in the houses with one heat pump the relay should be energized at a load somewhere between 5 and 8 KW and in the houses with two heat pumps at a load somewhere between 9 and 12 KW. This type of program device would probably require a water heater sized for off-peak heating to provide greater storage of hot water than is now possible. This type of replacement should be considered whenever an existing water heater has failed.

An off-peak water heating schedule controlled by a time clock could also be used to shift the water heating load to the night hours, but unless the hours of water heating were staggered after midnight, the time of maximum demand for the entire housing area might only be shifted to a new hour without reduction in magnitude. This device might still be practical, if it were found that the power demand of the air base outside the housing area became quite low at night.

The type of device which permitted either of two devices to be energized as required, but not both simultaneously, would probably reduce the maximum power demand in each house appreciably, but it might not reduce the high average that appears to have caused the maximum demand for the entire housing area.

It is recommended that water heaters with storage tanks suited to off-peak heating be installed whenever an opportunity for replacement occurs and that one or more of the program devices that would reduce the peaks and fill in the valleys of the daily demand curves be tried on a pilot basis. In our opinion, the program devices identified by the numbers (4), (6), (7) and (5) offer the best possibilities for reduction of maximum demand at the air base.

U.S. DEPARTMENT OF COMMERCE
Frederick H. Mueller, *Secretary*

NATIONAL BUREAU OF STANDARDS
A. V. Astin, *Director*

THE NATIONAL BUREAU OF STANDARDS

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ELECTRICITY. Resistance and Reactance. Electrochemistry. Electrical Instruments. Magnetic Measurements. Dielectrics.

METROLOGY. Photometry and Colorimetry. Refractometry. Photographic Research. Length. Engineering Metrology. Mass and Scale. Volumetry and Densimetry.

HEAT. Temperature Physics. Heat Measurements. Cryogenic Physics. Rheology. Molecular Kinetics. Free Radicals Research. Equation of State. Statistical Physics. Molecular Spectroscopy.

RADIATION PHYSICS. X-Ray. Radioactivity. Radiation Theory. High Energy Radiation. Radiological Equipment. Nucleonic Instrumentation. Neutron Physics.

CHEMISTRY. Surface Chemistry. Organic Chemistry. Analytical Chemistry. Inorganic Chemistry. Electrodeposition. Molecular Structure and Properties of Gases. Physical Chemistry. Thermochemistry. Spectrochemistry. Pure Substances.

MECHANICS. Sound. Pressure and Vacuum. Fluid Mechanics. Engineering Mechanics. Combustion Controls.

ORGANIC AND FIBROUS MATERIALS. Rubber. Textiles. Paper. Leather. Testing and Specifications. Polymer Structure. Plastics. Dental Research.

METALLURGY. Thermal Metallurgy. Chemical Metallurgy. Mechanical Metallurgy. Corrosion. Metal Physics.

MINERAL PRODUCTS. Engineering Ceramics. Glass. Refractories. Enameled Metals. Constitution and Microstructure.

BUILDING RESEARCH. Structural Engineering. Fire Research. Mechanical Systems. Organic Building Materials. Codes and Safety Standards. Heat Transfer. Inorganic Building Materials.

APPLIED MATHEMATICS. Numerical Analysis. Computation. Statistical Engineering. Mathematical Physics.

DATA PROCESSING SYSTEMS. Components and Techniques. Digital Circuitry. Digital Systems. Analog Systems. Applications Engineering.

ATOMIC PHYSICS. Spectroscopy. Radiometry. Mass Spectrometry. Solid State Physics. Electron Physics. Atomic Physics.

INSTRUMENTATION. Engineering Electronics. Electron Devices. Electronic Instrumentation. Mechanical Instruments. Basic Instrumentation.

Office of Weights and Measures.

BOULDER, COLO.

CRYOGENIC ENGINEERING. Cryogenic Equipment. Cryogenic Processes. Properties of Materials. Gas Liquefaction.

IONOSPHERE RESEARCH AND PROPAGATION. Low Frequency and Very Low Frequency Research. Ionosphere Research. Prediction Services. Sun-Earth Relationships. Field Engineering. Radio Warning Services.

RADIO PROPAGATION ENGINEERING. Data Reduction Instrumentation. Radio Noise. Tropospheric Measurements. Tropospheric Analysis. Propagation-Terrain Effects. Radio-Meteorology. Lower Atmosphere Physics.

RADIO STANDARDS. High frequency Electrical Standards. Radio Broadcast Service. Radio and Microwave Materials. Atomic Frequency and Time Standards. Electronic Calibration Center. Millimeter-Wave Research. Microwave Circuit Standards.

RADIO SYSTEMS. High Frequency and Very High Frequency Research. Modulation Research. Antenna Research. Navigation Systems. Space Telecommunications.

UPPER ATMOSPHERE AND SPACE PHYSICS. Upper Atmosphere and Plasma Physics. Ionosphere and Exosphere Scatter. Airglow and Aurora. Ionospheric Radio Astronomy.

NBS